Spill Modeling for Response, Planning & Evaluation

Global Hindcast / Nowcast / Forecast System

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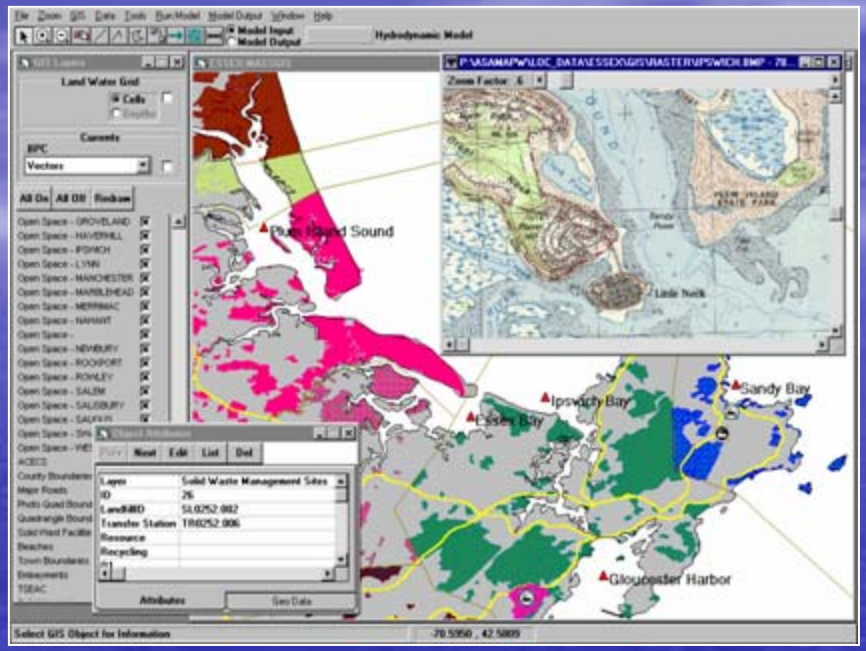
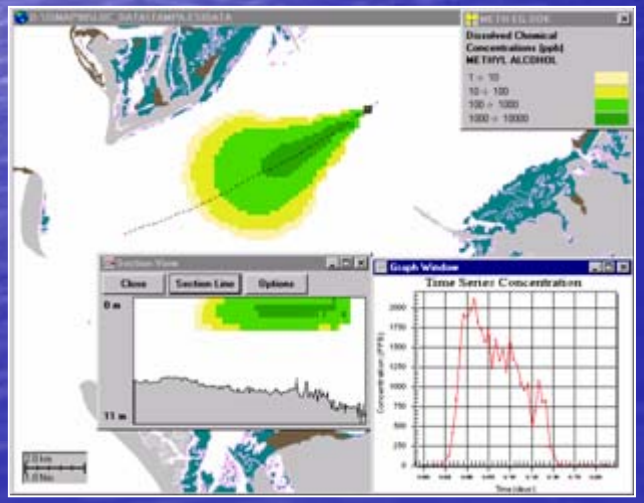
Outline

- ASA Spill Modeling and Analysis Systems
- Models – Application Methods for Spills
- Oil Models – Processes Simulated
- Example – Single Scenario (e.g. SONS)
- Example – Pre-Planning and Evaluations of Risk

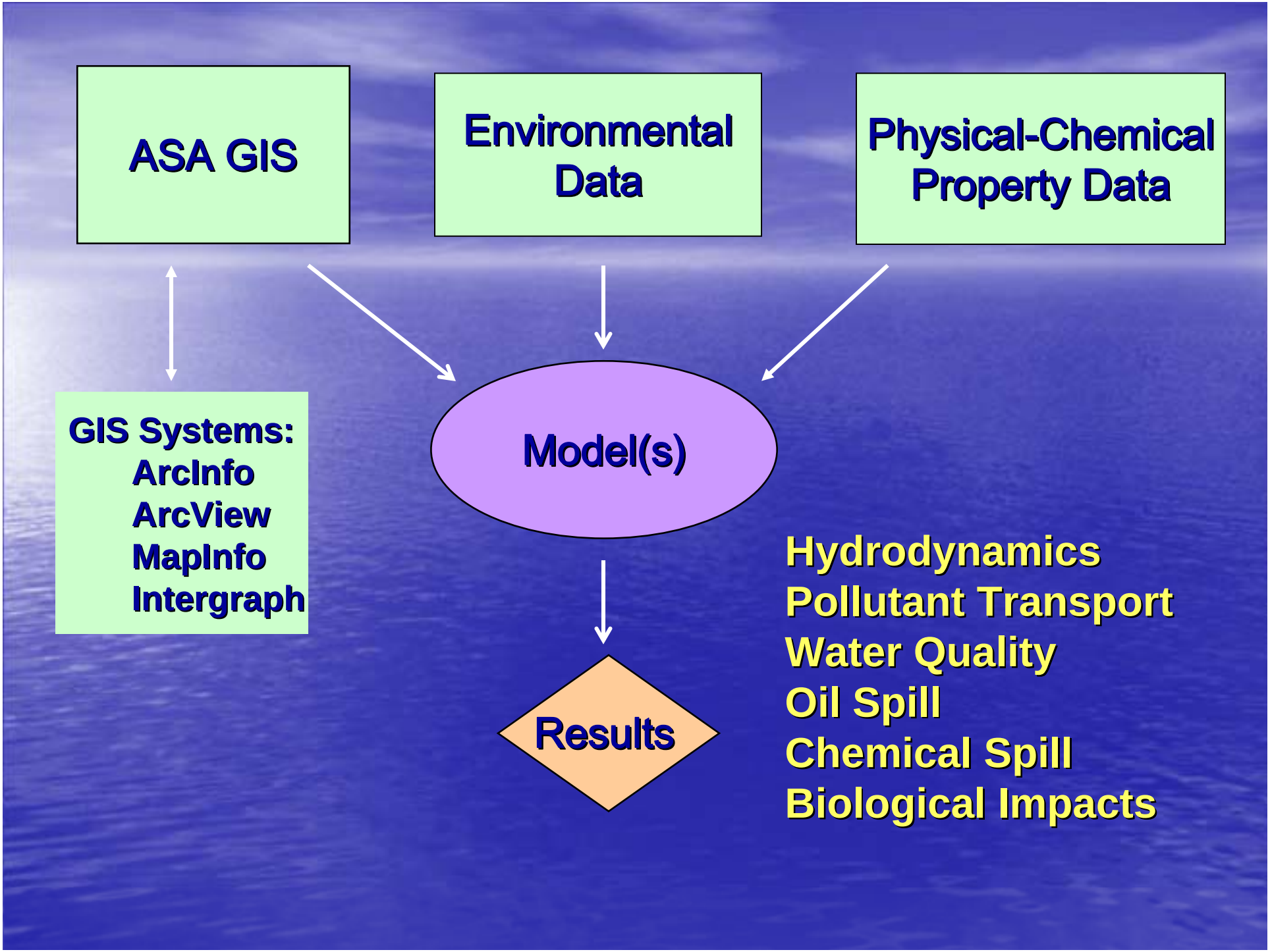
ASA – Modeling and Analysis

- Oil and Chemical Spills
- Hydrodynamics
- Pollutant Transport
- Water Quality
- Biological Impacts
- Ecological Risk
- Natural Resource Damage Assessment
- Search and Rescue



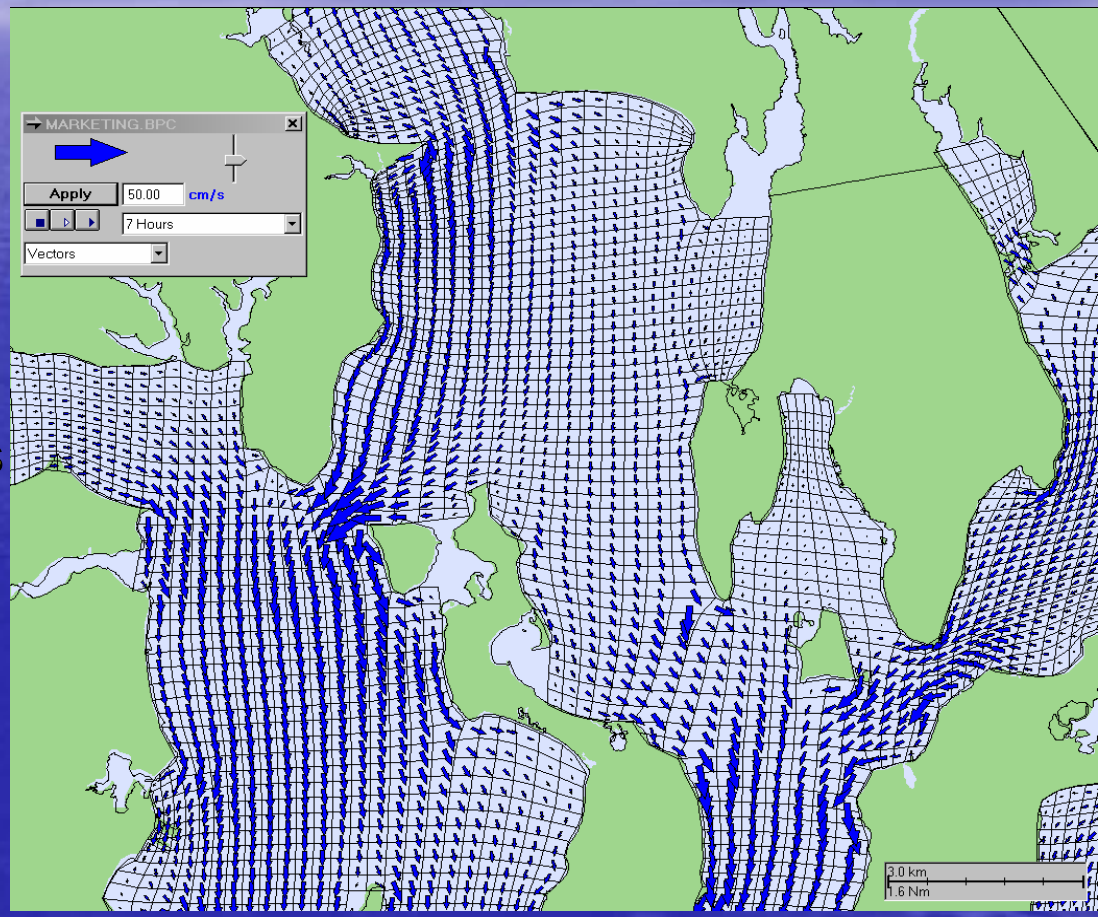


- Windows Graphical User Interface (GUI)
- Geographical Information Systems (GIS)
- Real-Time Data Integration


ASA GIS
Environmental Data
Physical-Chemical Property Data
GIS Systems:
ArcInfo
ArcView
MapInfo
Intergraph
Model(s)
Results
Hydrodynamics
Pollutant Transport
Water Quality
Oil Spill
Chemical Spill
Biological Impacts

Hydrodynamic Modeling

- 2D and 3D
- Gridding:
  - Rectilinear
  - Boundary- fitted
- Dated
  - Run for specific time
  - Sum pre-run components
- Components
  - Tidal
  - Wind-driven
  - Density-driven
  - River

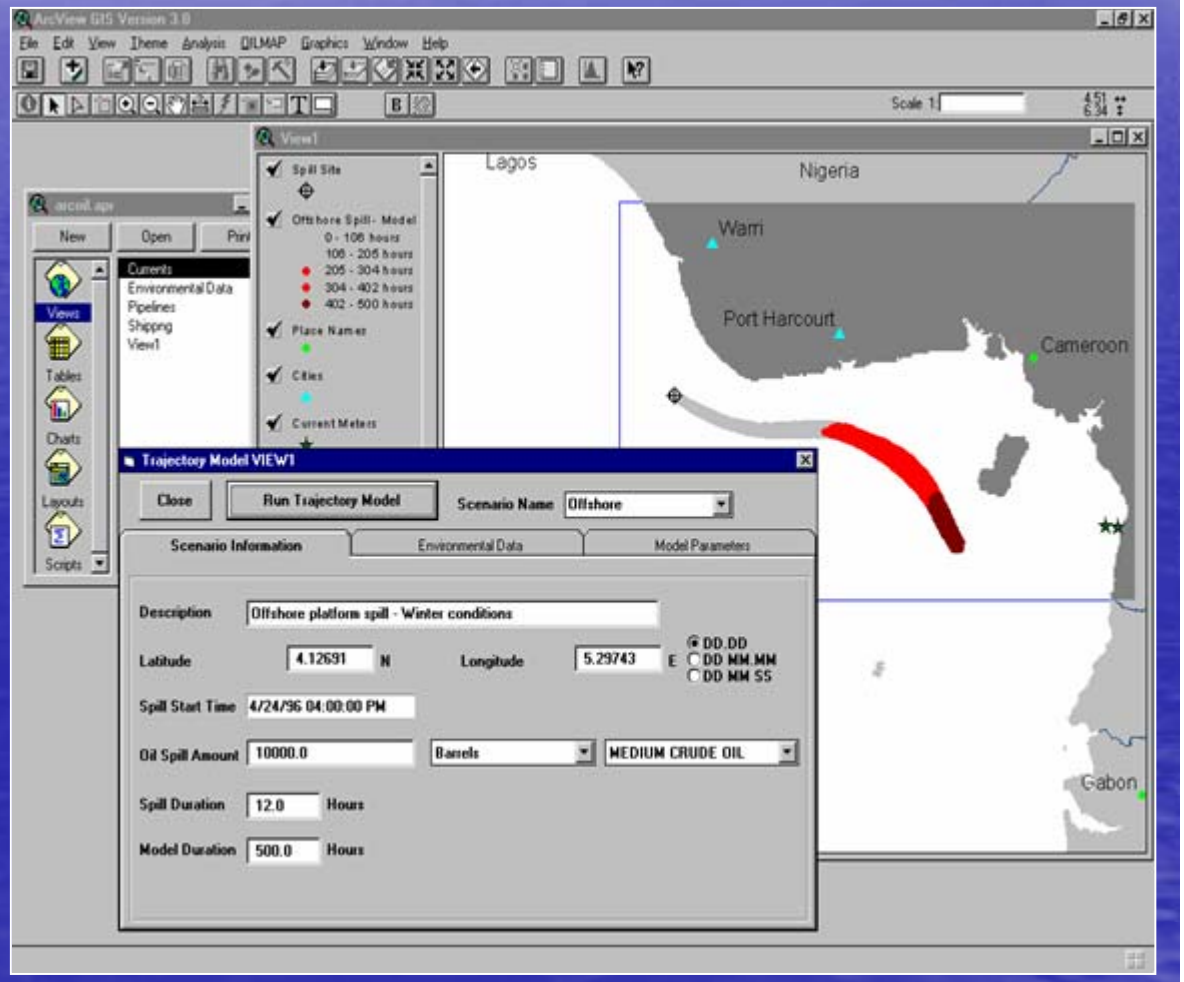


Response Models

- Oil Spills: OILMAP, SIMAP
- Chemical Spills: CHEMMAP
- Air contamination: AIRMAP
- Search and Rescue: SARMAP
- CMSMAP: Integrated system

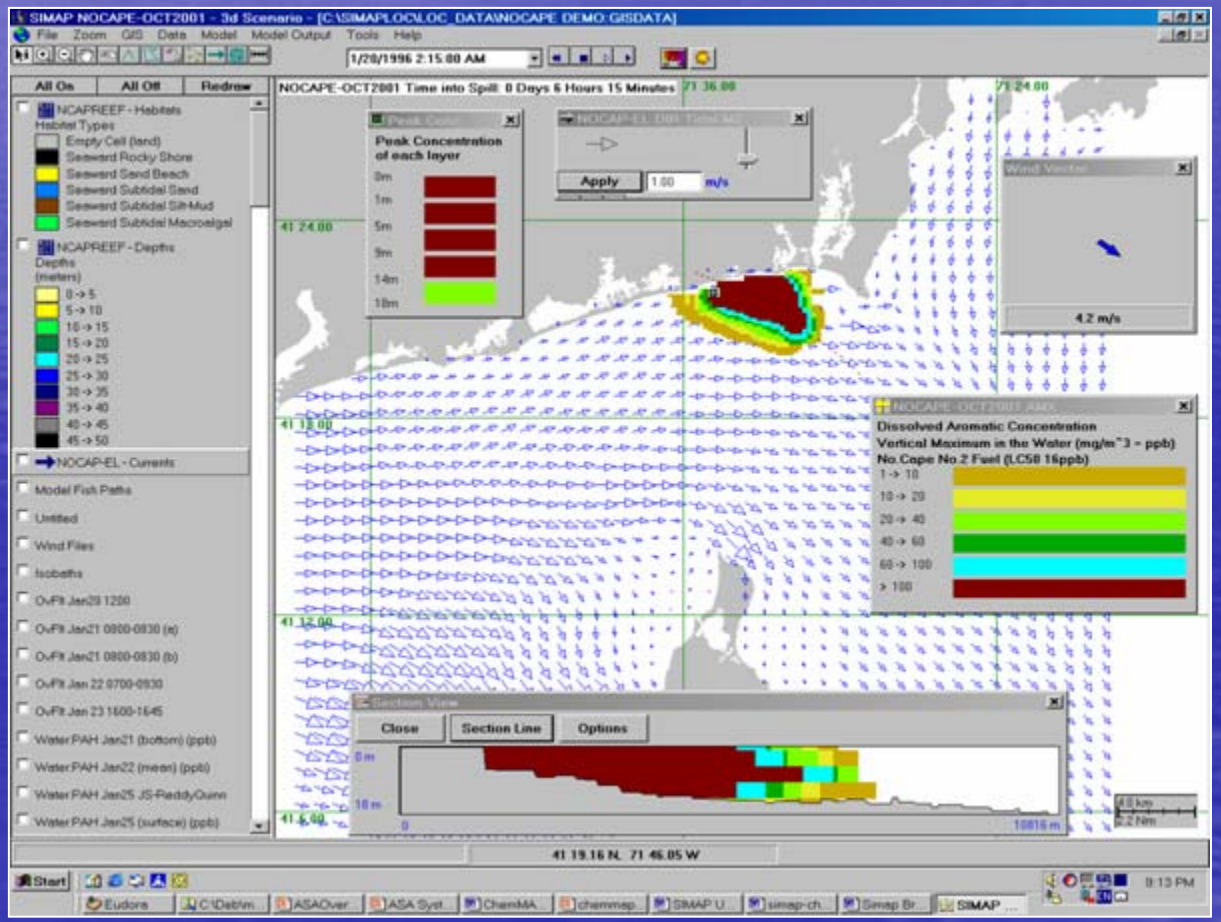
OILMAP

- Oil spill response
  - real time
  - decision support
  - training
- Spill drills
- Contingency planning
- Management and communication of spill-related data
- Linkage to ICS-based On-Scene Command and Control System (OSC2) – USCG



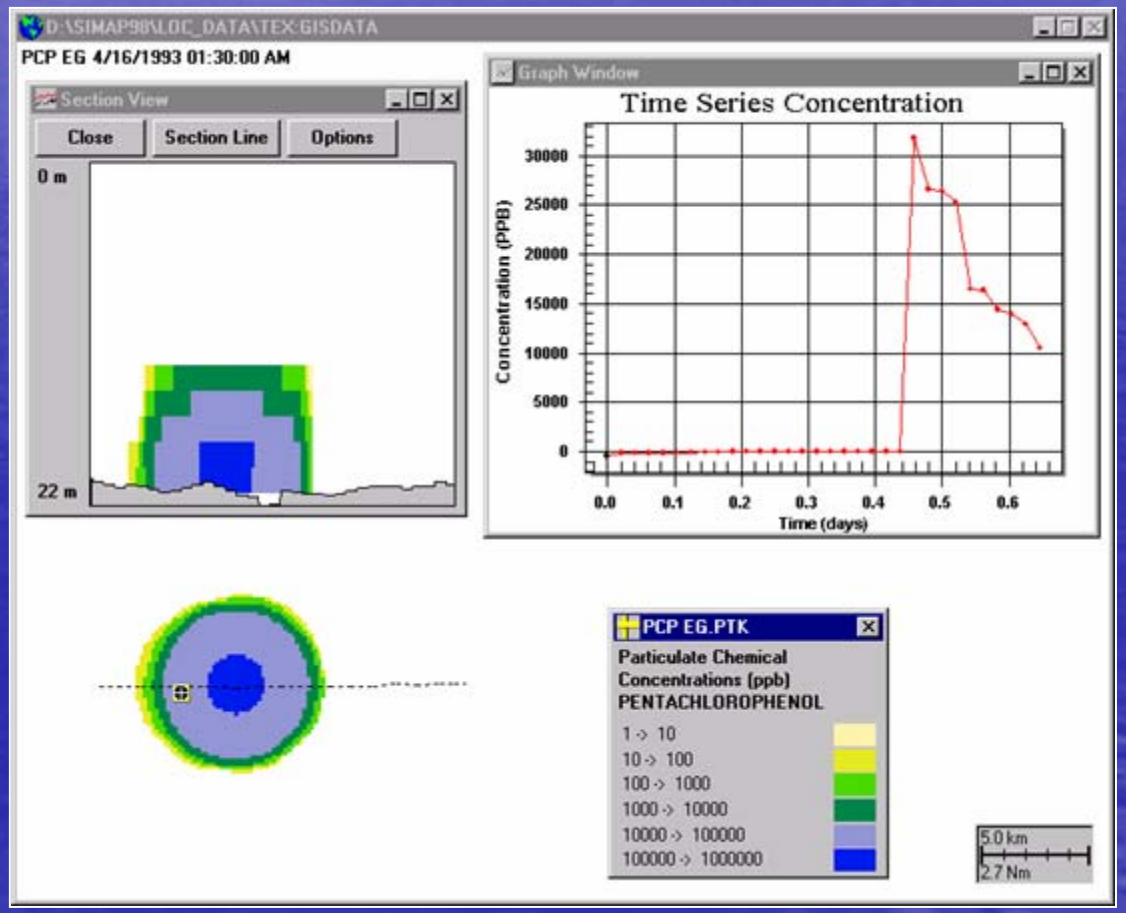
SIMAP

- Oil Spill Modeling: 3D Fates and Effects
- Spill planning
- Impact Assessment
- Ecological Risk Assessment
- Natural Resource Damage Assessment



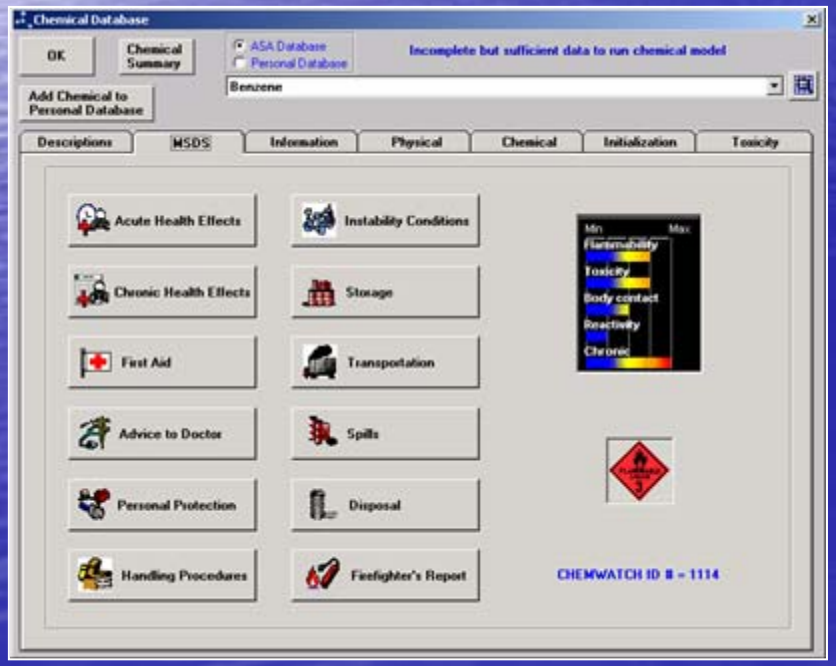
CHEMMAP

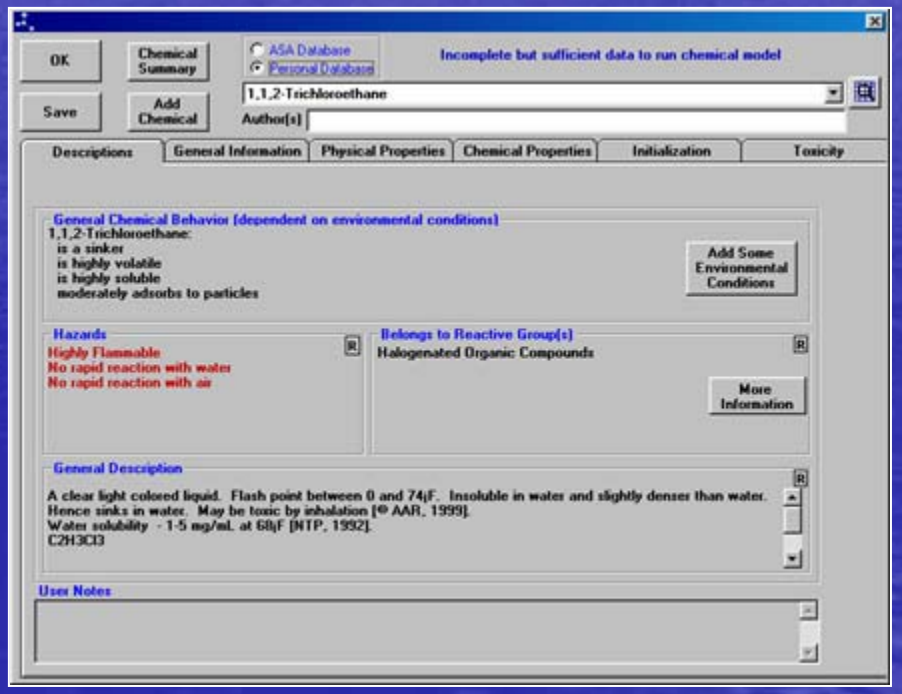
- Chemical Spill Modeling: 3D Fate and Effects
- Response
- Impact Assessment
- Ecological Risk Assessment
- Natural Resource Damage Assessment



Chemical Database

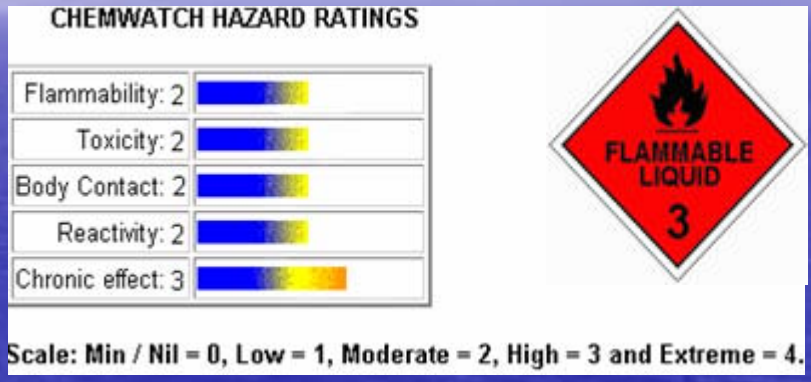
- Physical-chemical properties
- Hazards and spill behavior
- Over 900 chemicals





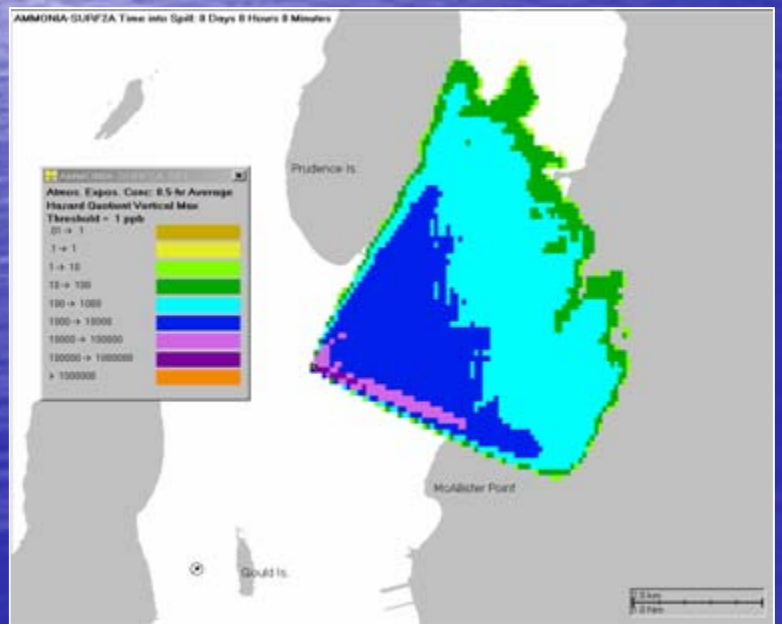
CHEMMAP Health & Safety

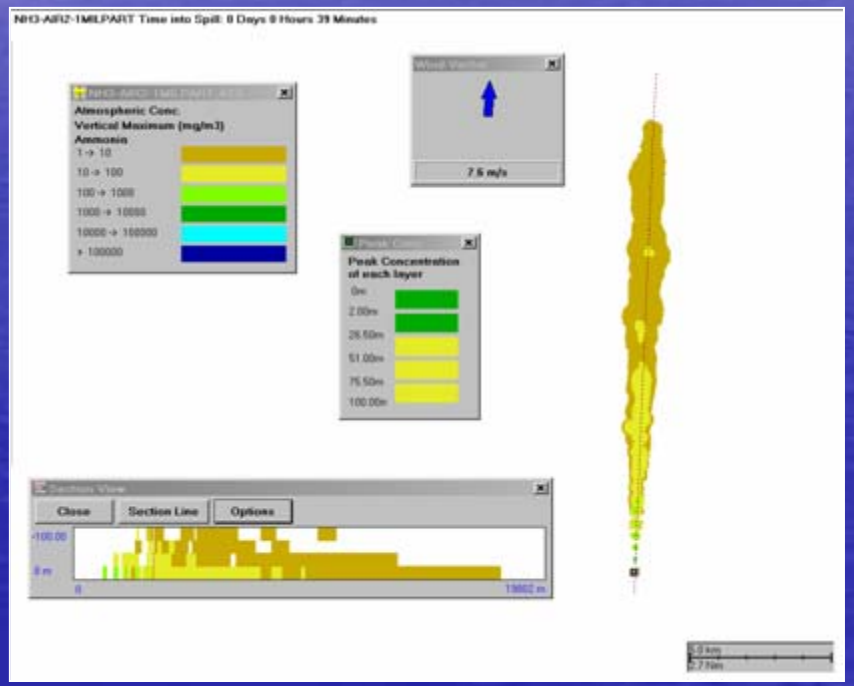
- Hazard Table and Precautions
- Acute and Chronic Health Effects
- First Aid and Advice for Doctors
- Personal Protective Equipment For Industrial/Commercial Environments
- Safe Handling
- Fire Fighting and Fire Incompatibility



AIRMAP

- Chemical transport modeling in air resulting from point release
- Sources:
  - Surface
  - From water

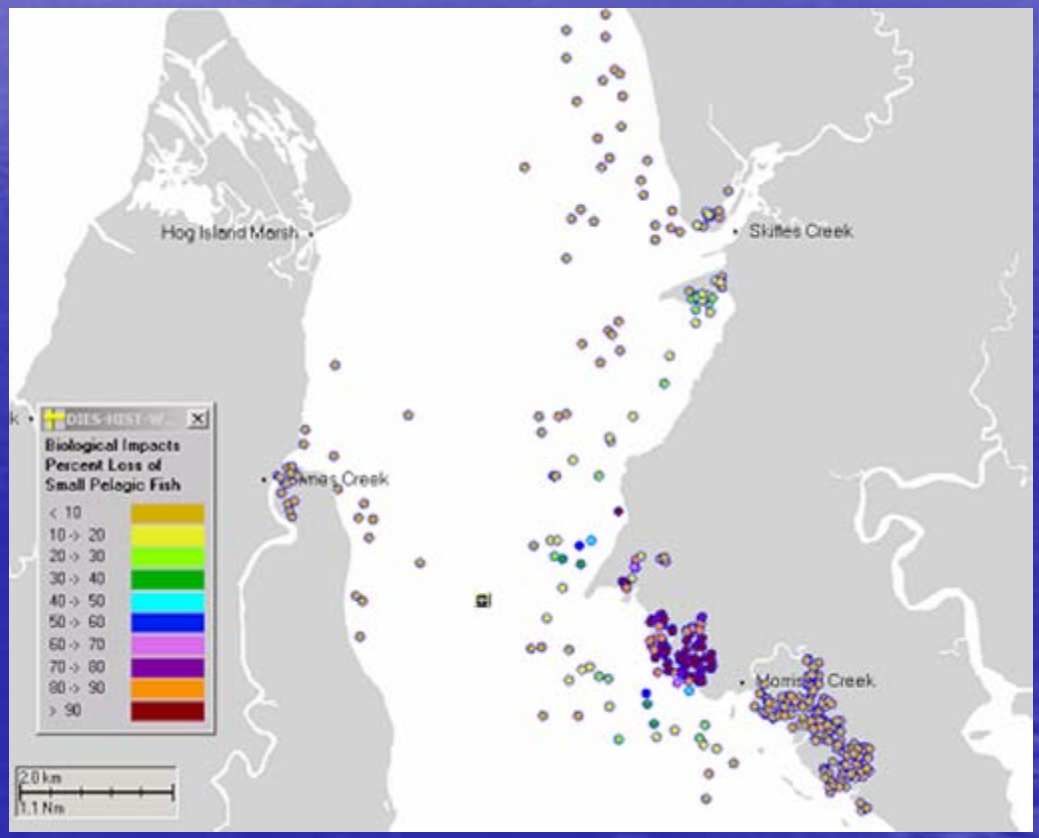




- Human exposure and hazard analysis

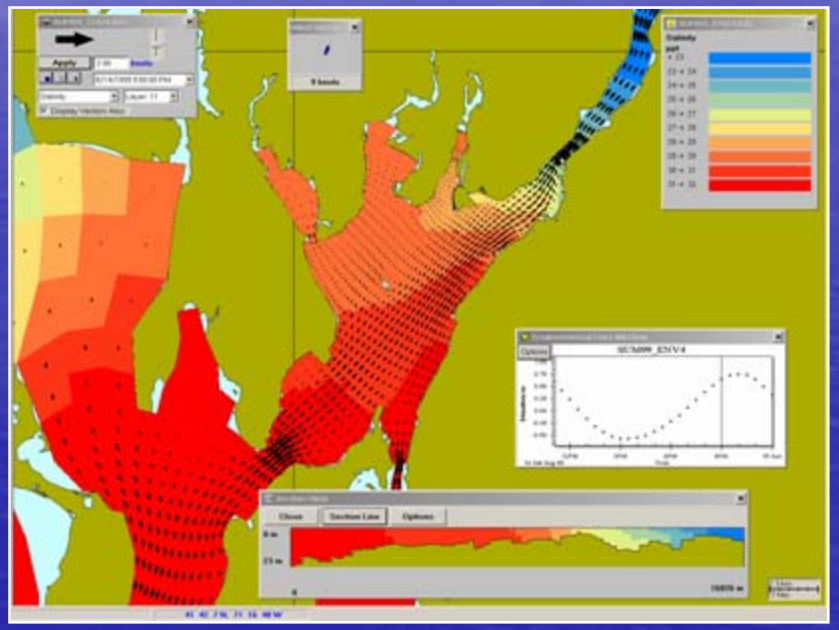
Biological Exposure Modeling

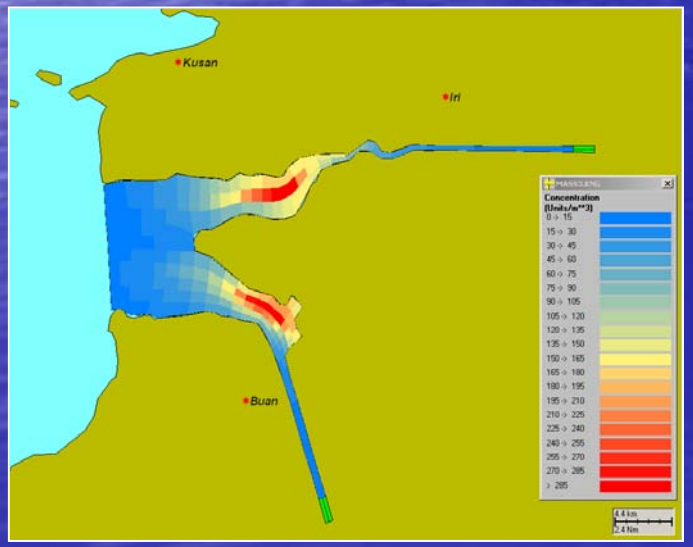
- Exposure to
  - Oil
  - Chemical
  - Sediments
- Track movements and exposure concentrations
- Dose: ppb-hours
- Percent Mortality
- Impacts if abundance known



WQMAP

- Pollutant Transport
- Point and Non-point Sources
- Water Quality
- Thermal Effluents

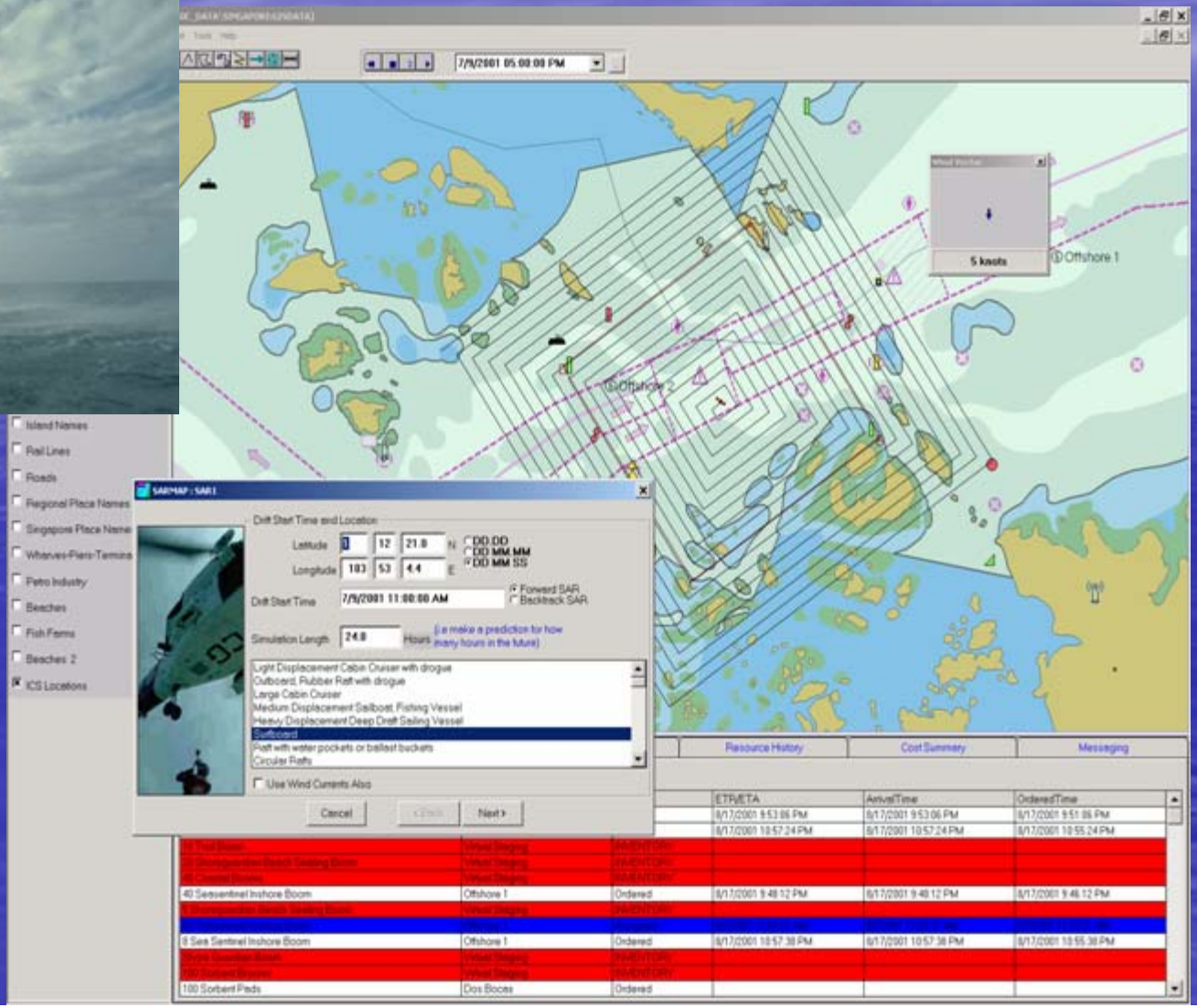




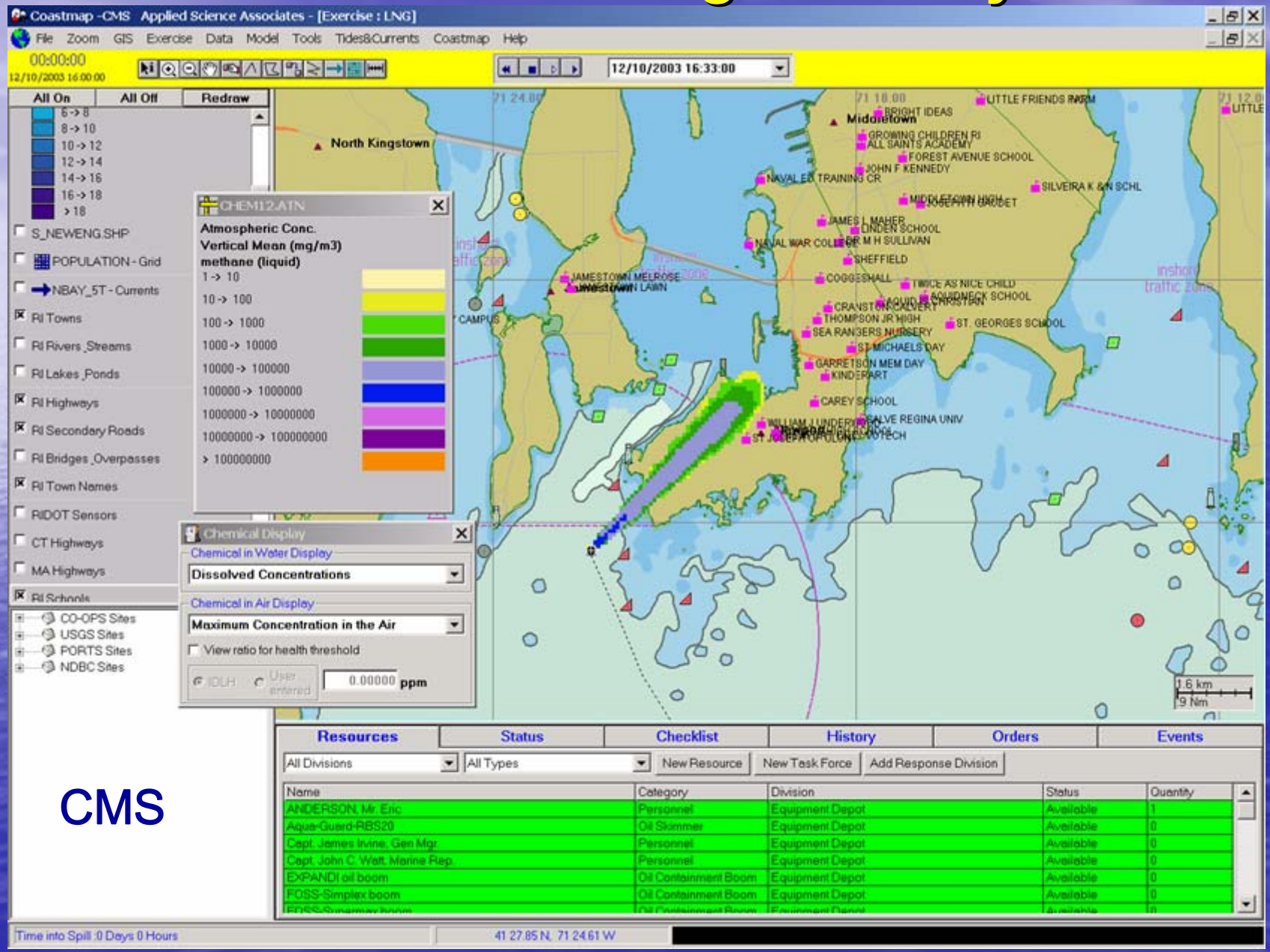
Search & Rescue Management System

SAROPS - USCG

SARMAP - US Navy

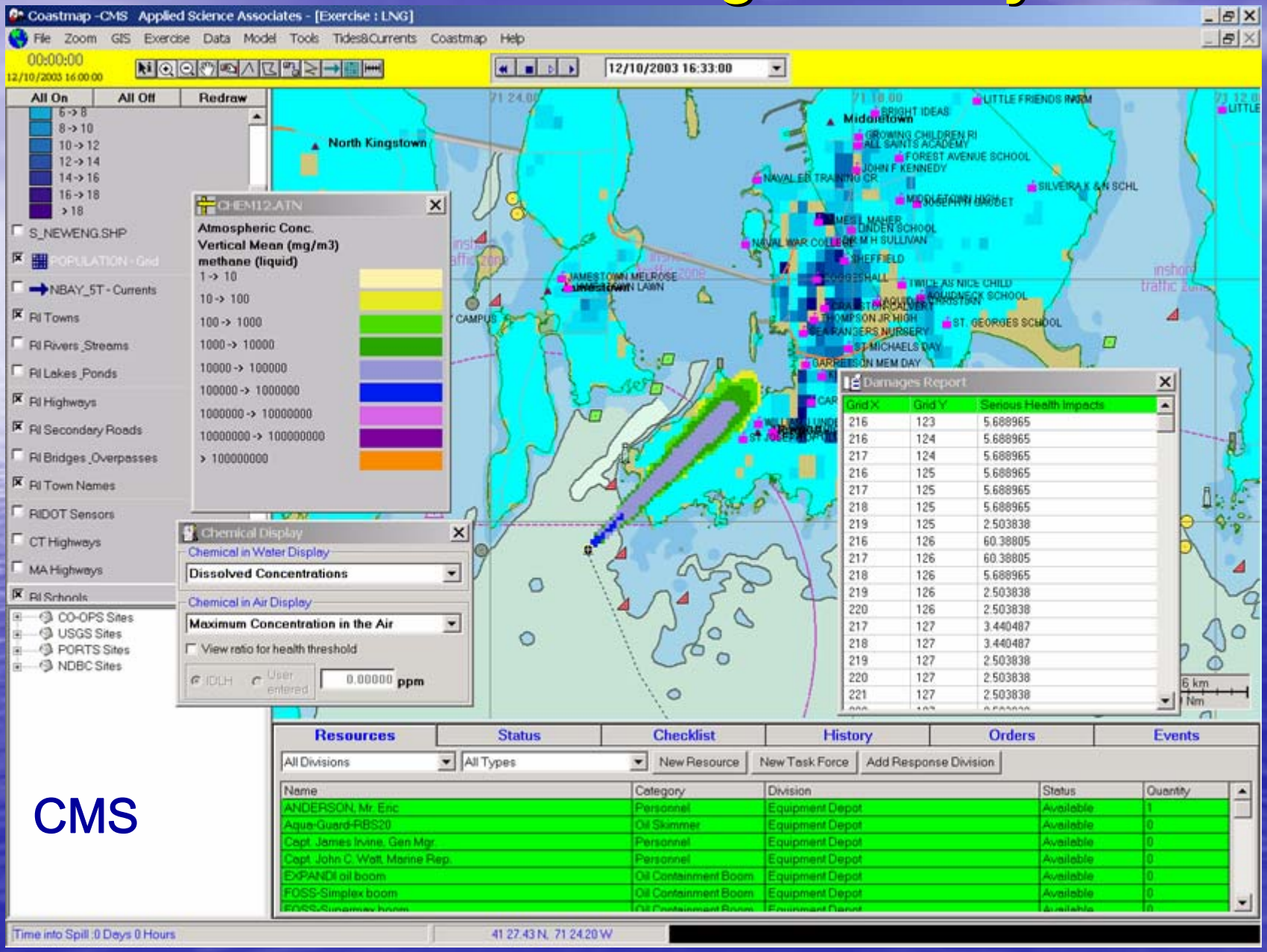


CMS = Crisis Management System

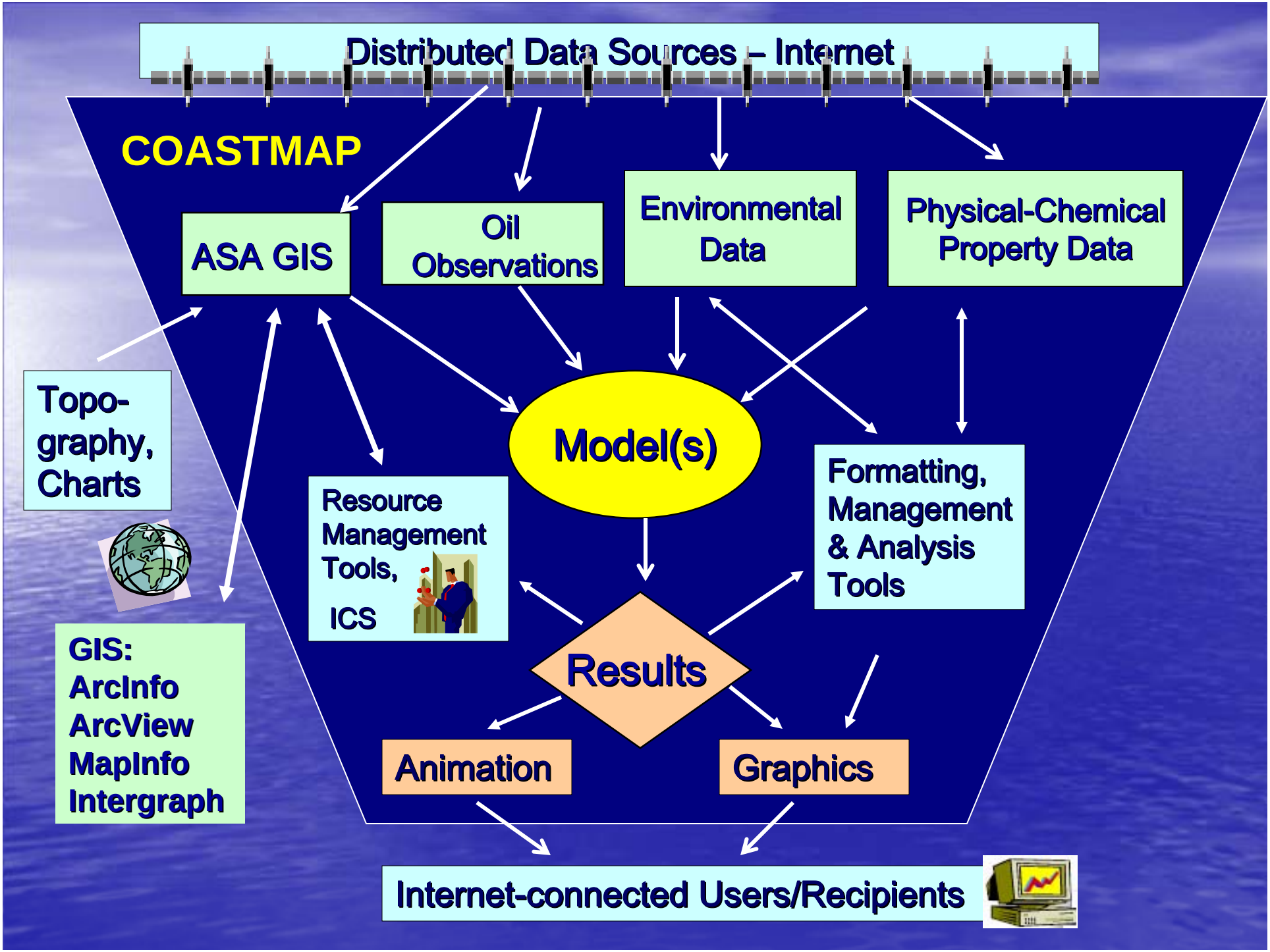


CMS

CMS = Crisis Management System

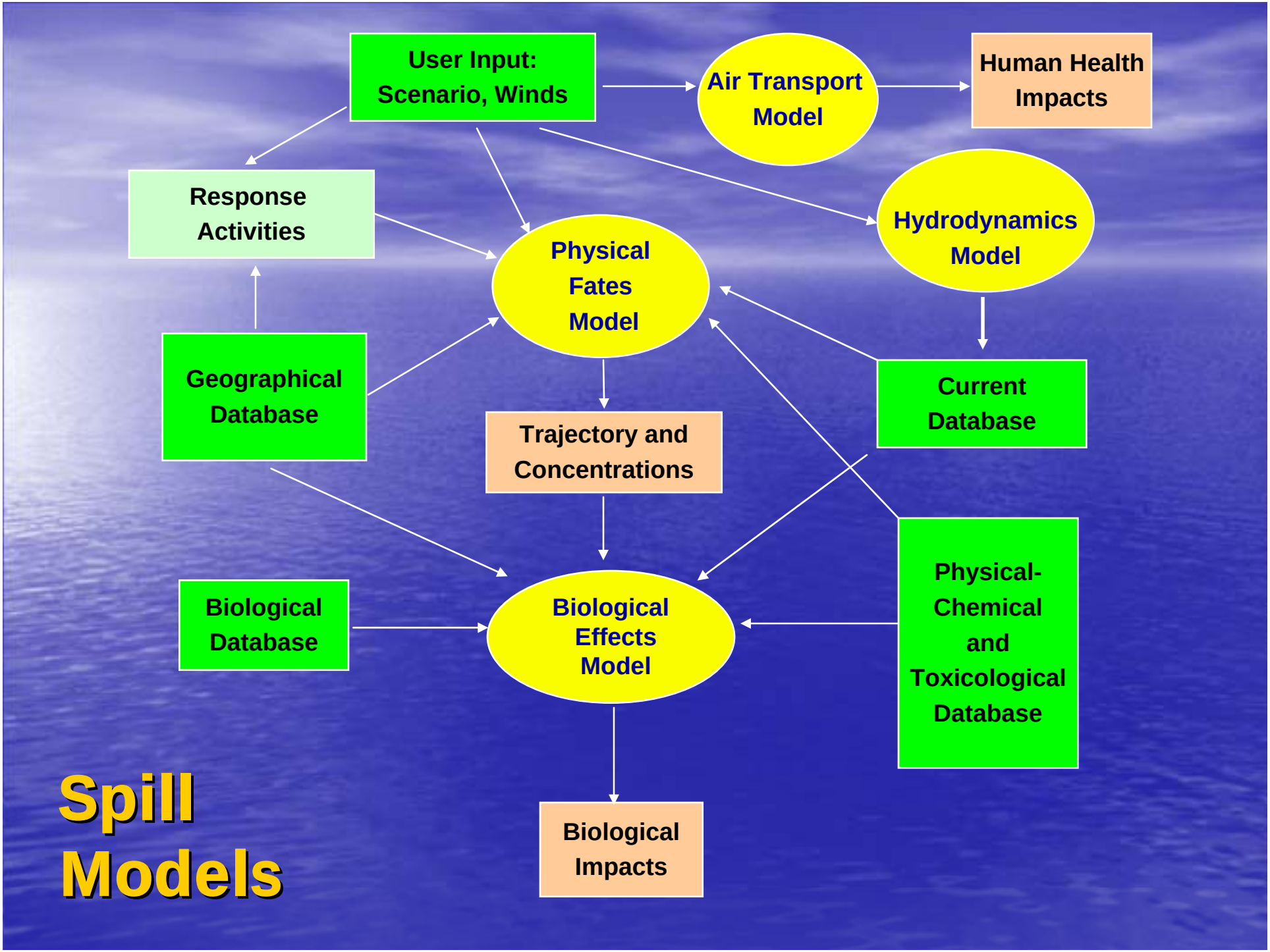


CMS

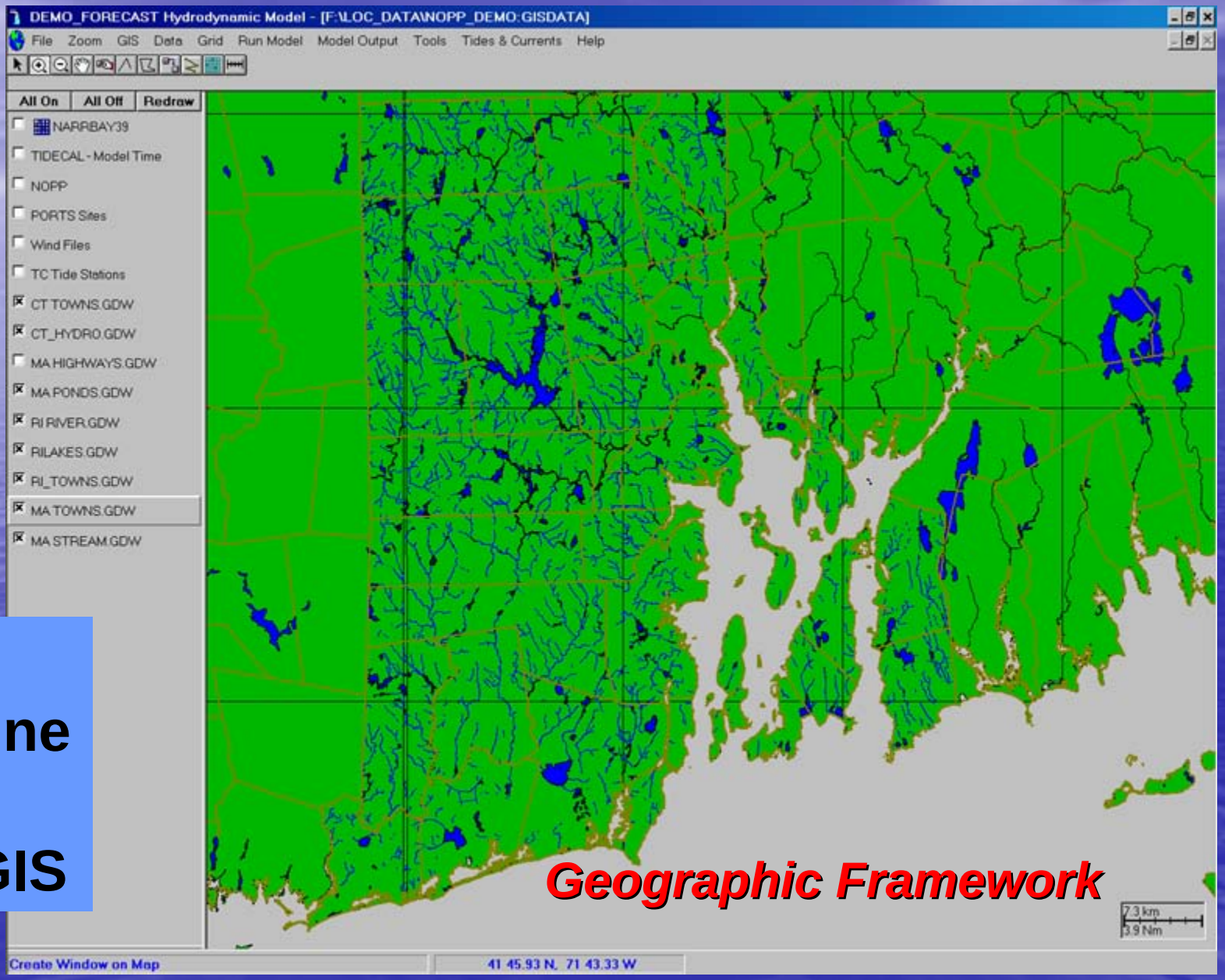

Distributed Data Sources – Internet
COASTMAP
ASA GIS
Oil Observations
Environmental Data
Physical-Chemical Property Data
Topo-graphy, Charts
Model(s)
Resource Management Tools, ICS
Formatting, Management & Analysis Tools
GIS: ArcInfo ArcView MapInfo Intergraph
Results
Animation
Graphics
Internet-connected Users/Recipients

COASTMAP

- Real-Time Data Collection and Archiving
- Analysis and QA/QC of Data Streams
- Embedded Geographic Information System (GIS)
- Seamless Linkage to Numerical Hindcast/Nowcast/Forcast Models


User Input: Scenario, Winds
Air Transport Model
Human Health Impacts
Response Activities
Hydrodynamics Model
Physical Fates Model
Geographical Database
Current Database
Trajectory and Concentrations
Physical-Chemical and Toxicological Database
Biological Database
Biological Effects Model
Biological Impacts
Spill Models

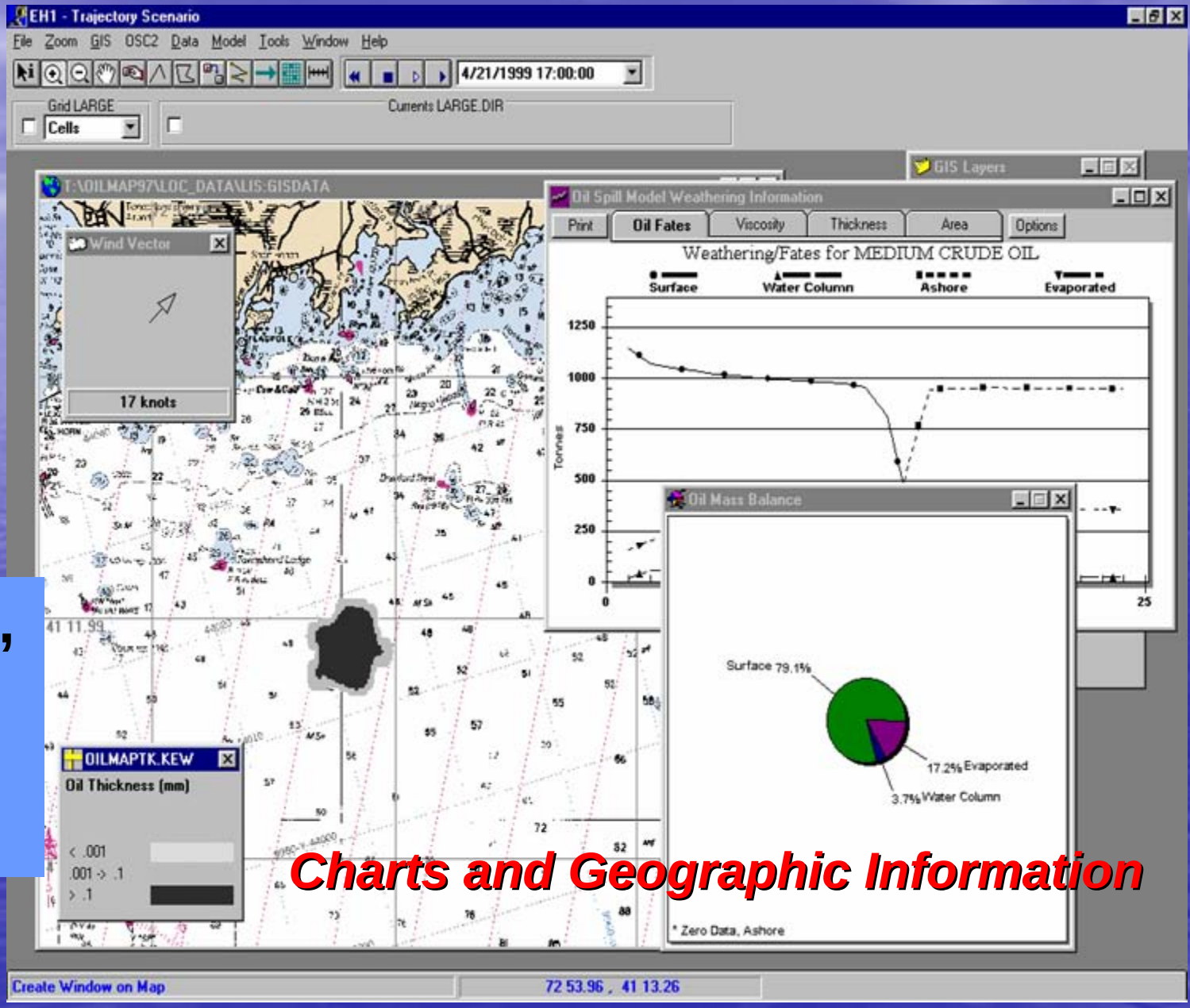
From Concept to Execution



Global Coastline Data; State GIS

Geographic Framework

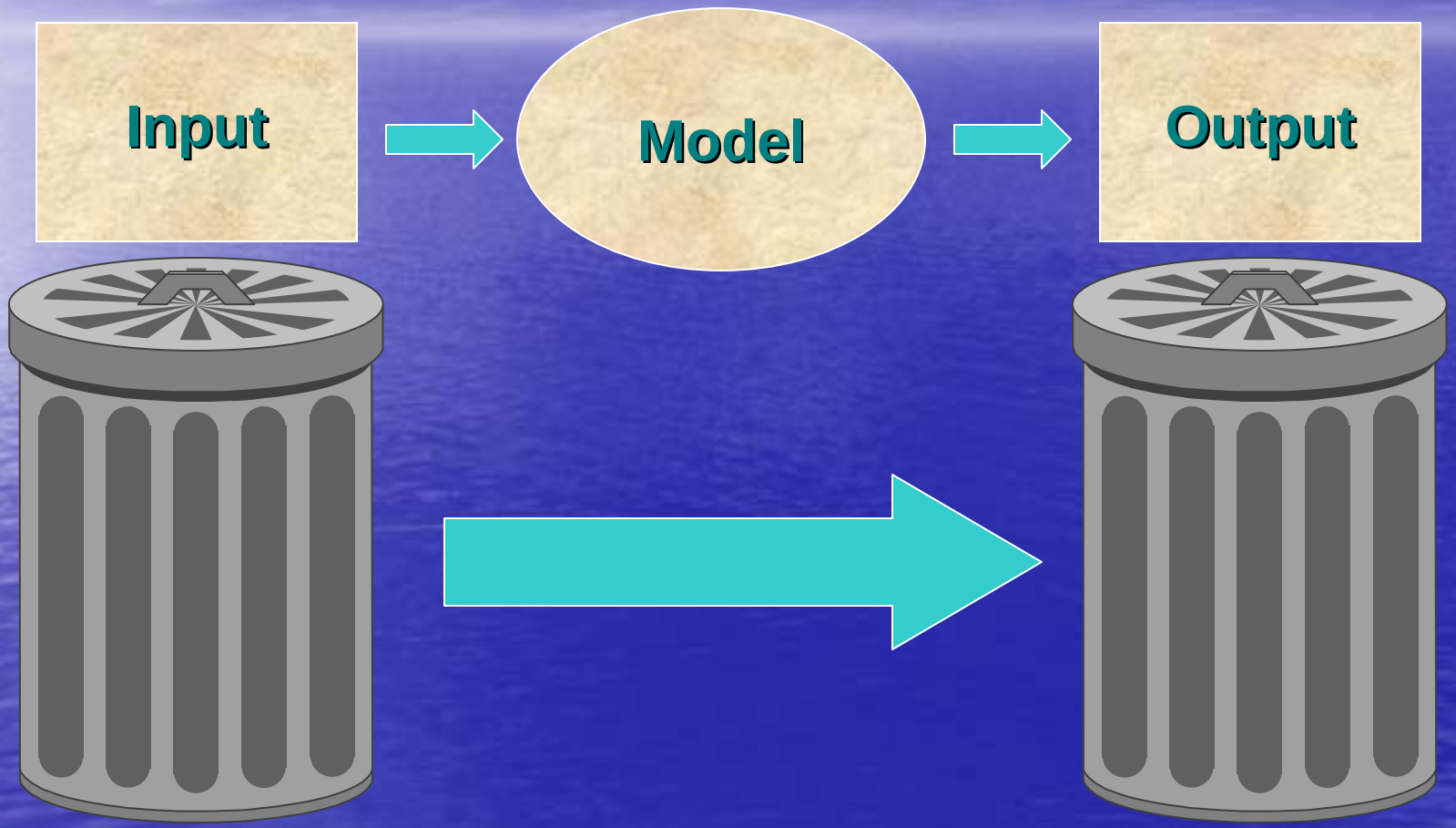
ASA GIS, BSB NOAA Charts



Charts and Geographic Information

Forecast Model Data Integration

Model Accuracy Depends on the Accuracy of Wind and Current Data



Independent Variable

Dependent Variable

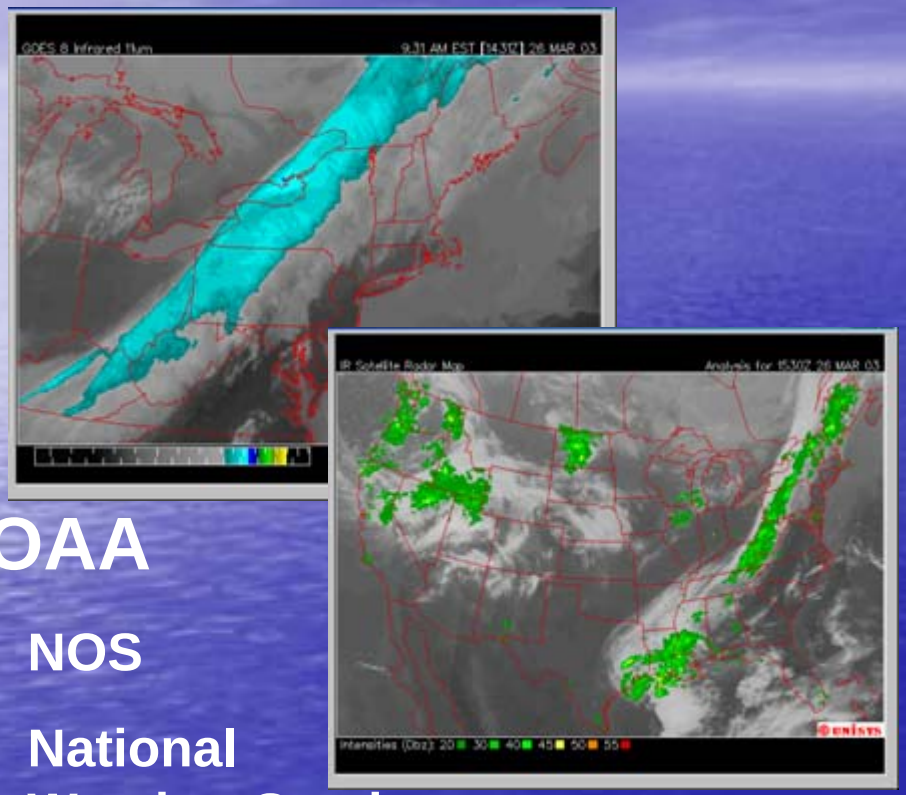
Real Time Data Collection

Meteorological: Wind, Waves, Temperature

Reliability:

✓Measured

•Forecasts



NOAA

NOS

National Weather Service

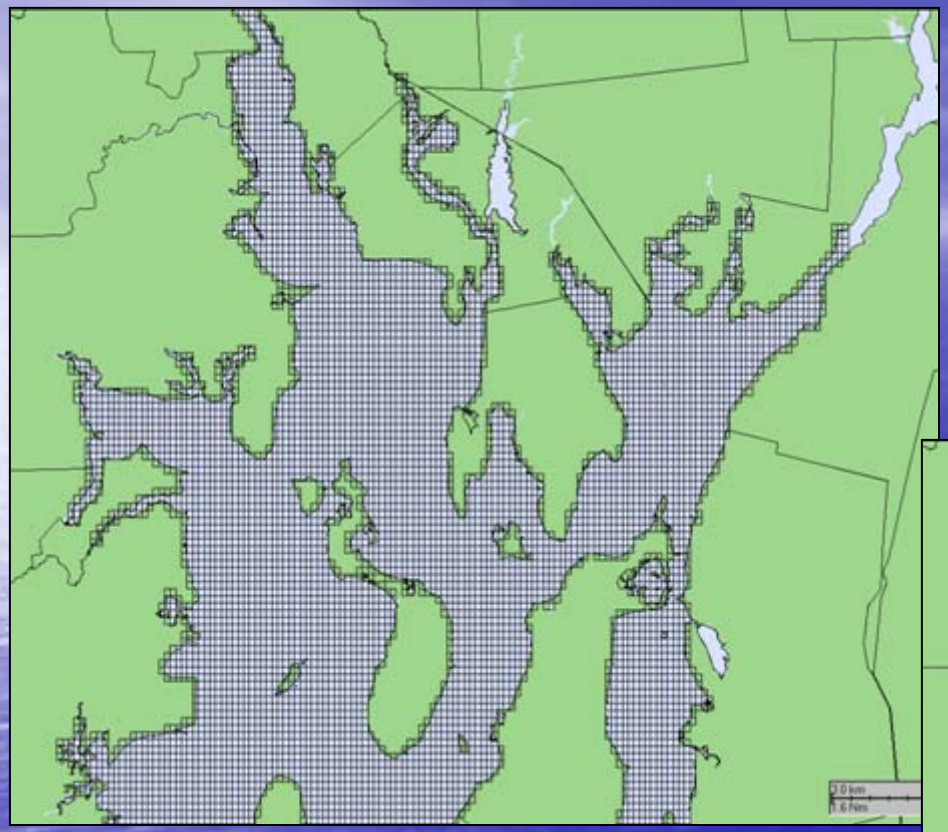
Current Data – Approach: Hydrodynamic Modeling

- Needed Input (in Real Time)
  - Forcing data
    - Water heights
    - Water density
    - River flow rates
  - Boundary conditions
- Observational data in real time
  - Calibration
  - Validation

Hydrodynamic Modeling Approach

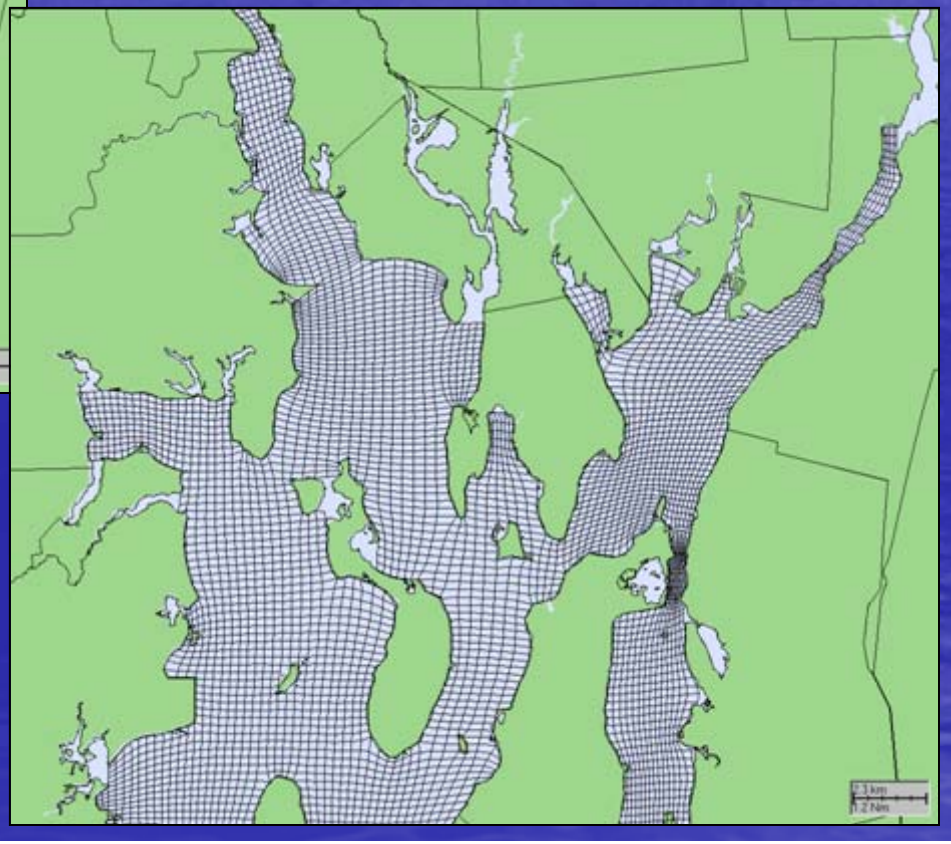
- Real-Time, Dated Simulation
  - Tidal constituents
  - Winds
  - River flow
  - Water density data
- Preparatory – pre-run constituents
  - Tidal harmonics
  - Seasonal mean or wet/dry season river flow
  - Sum components for date of spill
  - Add wind-driven component

Hydrodynamic Modeling



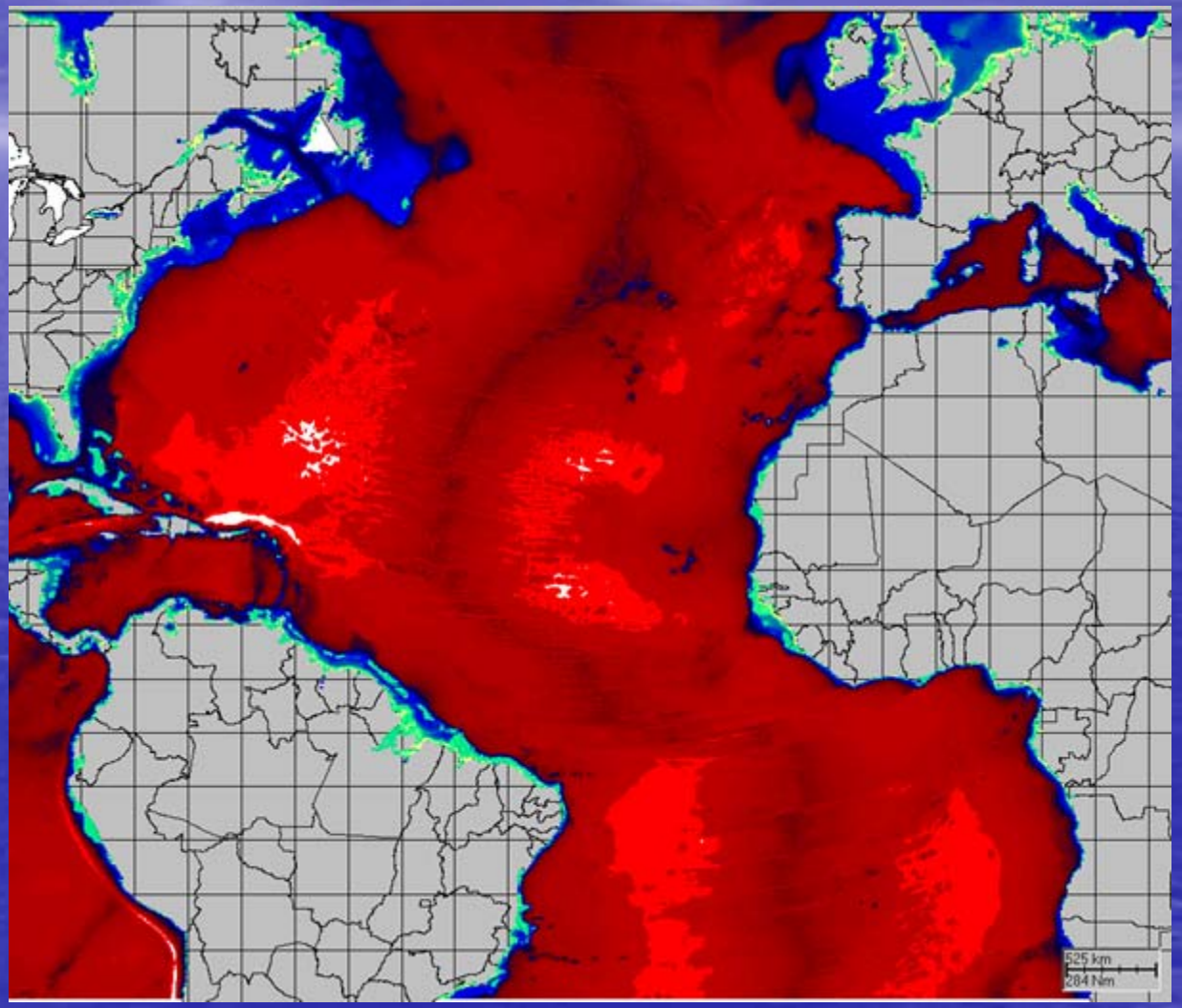
Rapid Rectangular Grid Generation

Boundary Conforming Grid Generation



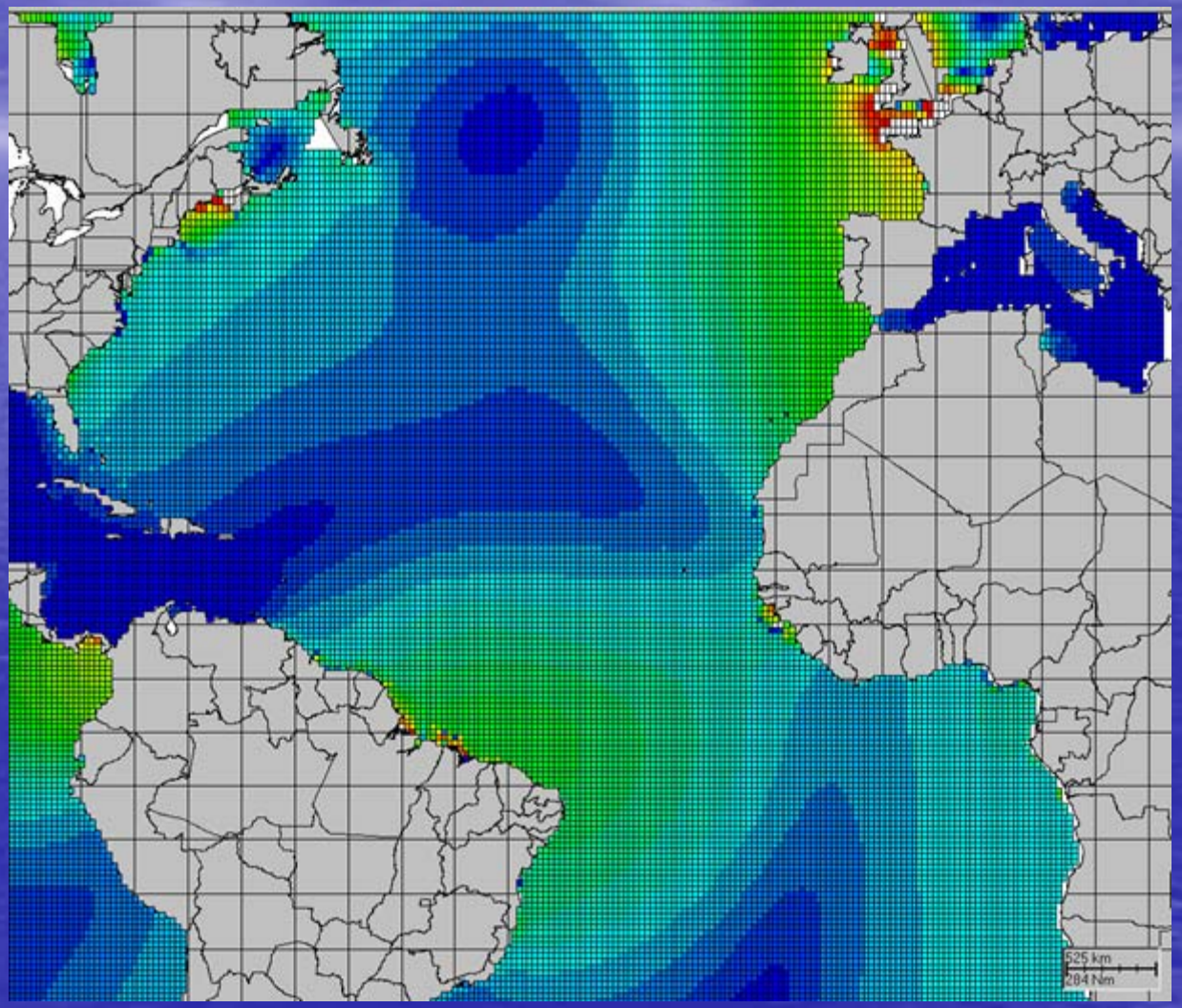
Global and US Databases

- Bathymetry
  - •ETOPO2
  - •NOAA



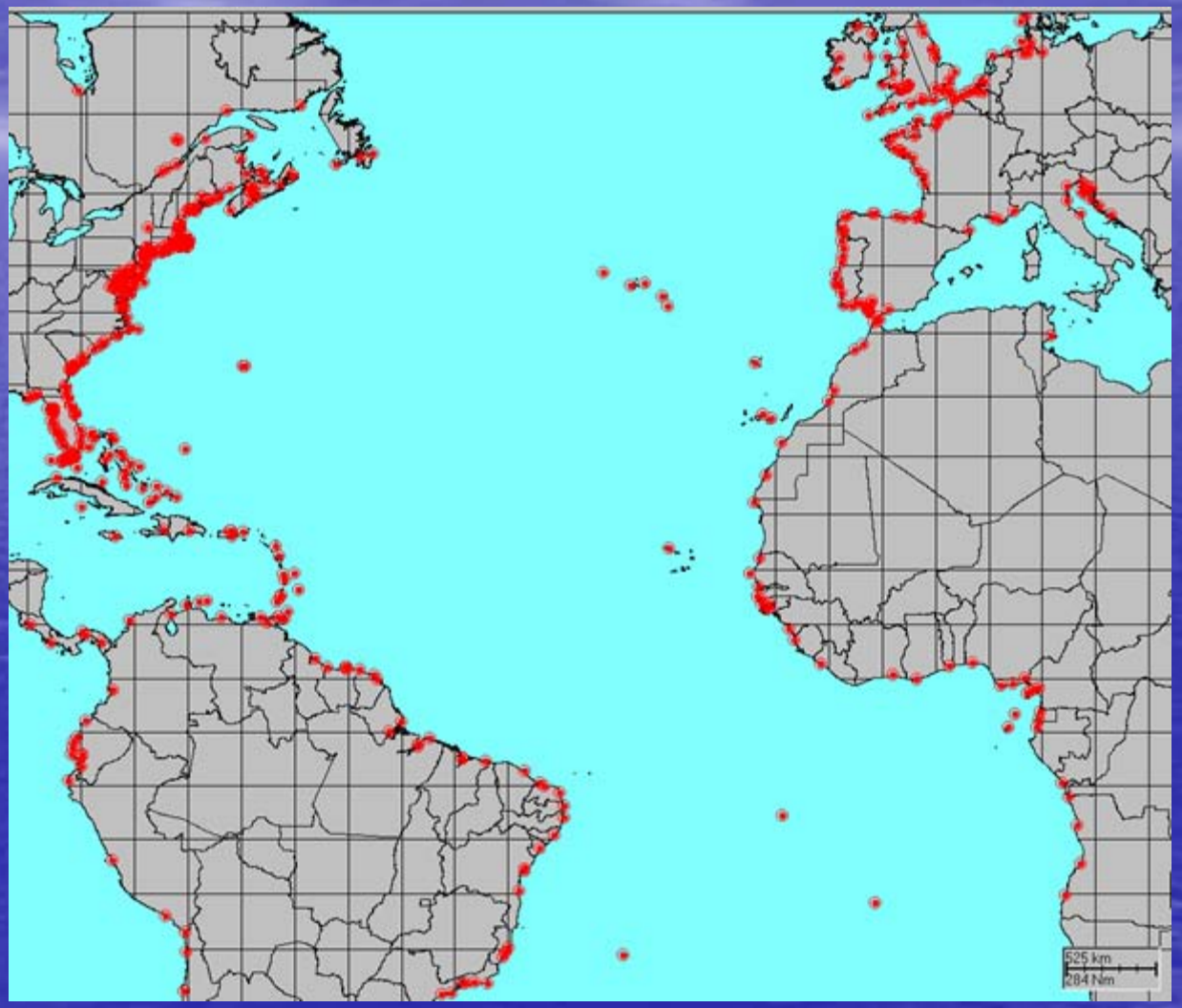
Global Databases

- Bathymetry
- Gridded Tidal Harmonics



Global Databases

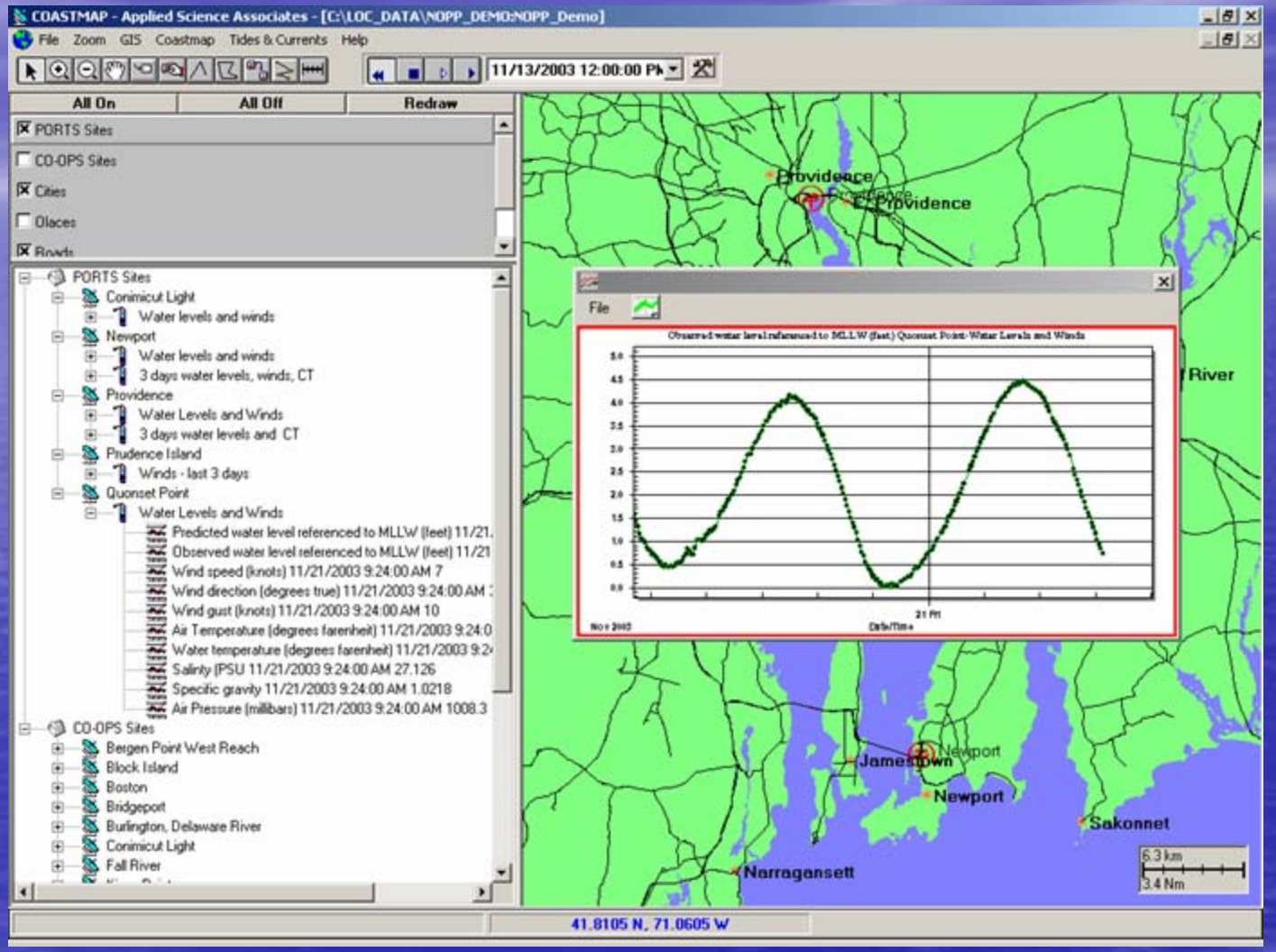
- Bathymetry
- Gridded Tidal Harmonics
- Point Coastal Tidal Harmonics



COASTMAP

Real-time connection to web data

- **NOAA**
  - **PORTS sensors**
  - **CO-OPS**
  - **NDBC**
- **USGS gauges**

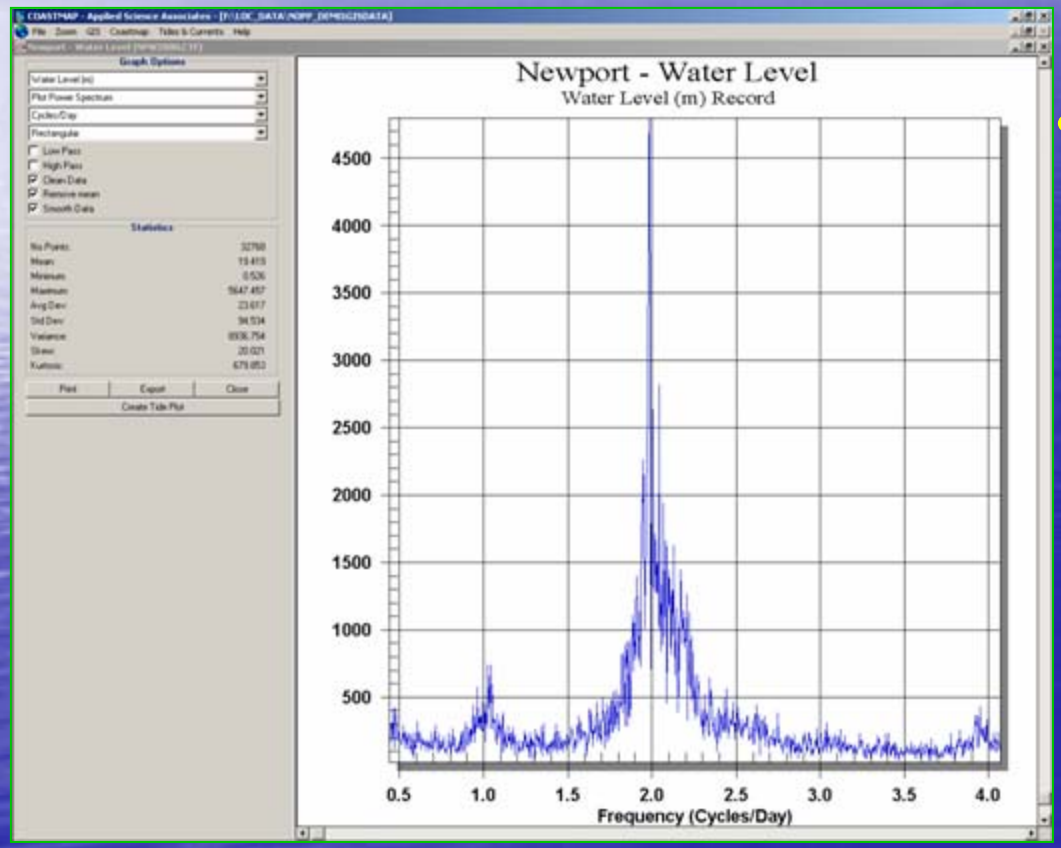


Distributed Data Sources

- **Real-Time Systems**
  - NOAA PORTS
  - GOMOOS
  - CODAR
  - USGS
  - User Field Programs
- **Archived Data**
  - National Weather Service
  - NOAA Buoys
  - USGS
  - User Archives
- **Models**
  - NOAA ETSS
  - NOAA NBLAPS
  - SWAFS
  - ASA Forecasting System (NOPP)

COASTMAP

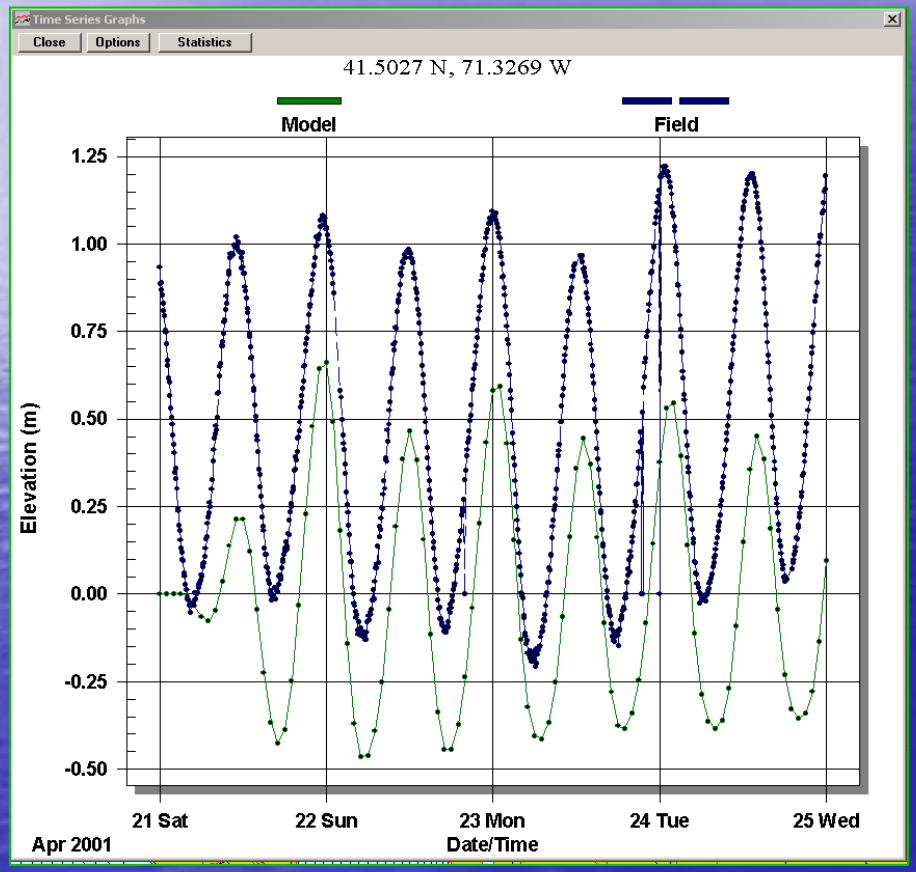
Data Visualization and Analysis



- **Perform a suite of common data analysis functions**
  - **Filtering**
  - **Power Spectrum**
  - **Demeaning**
  - **Removal of Spurious Data**
  - **Harmonic Analysis**

COASTMAP

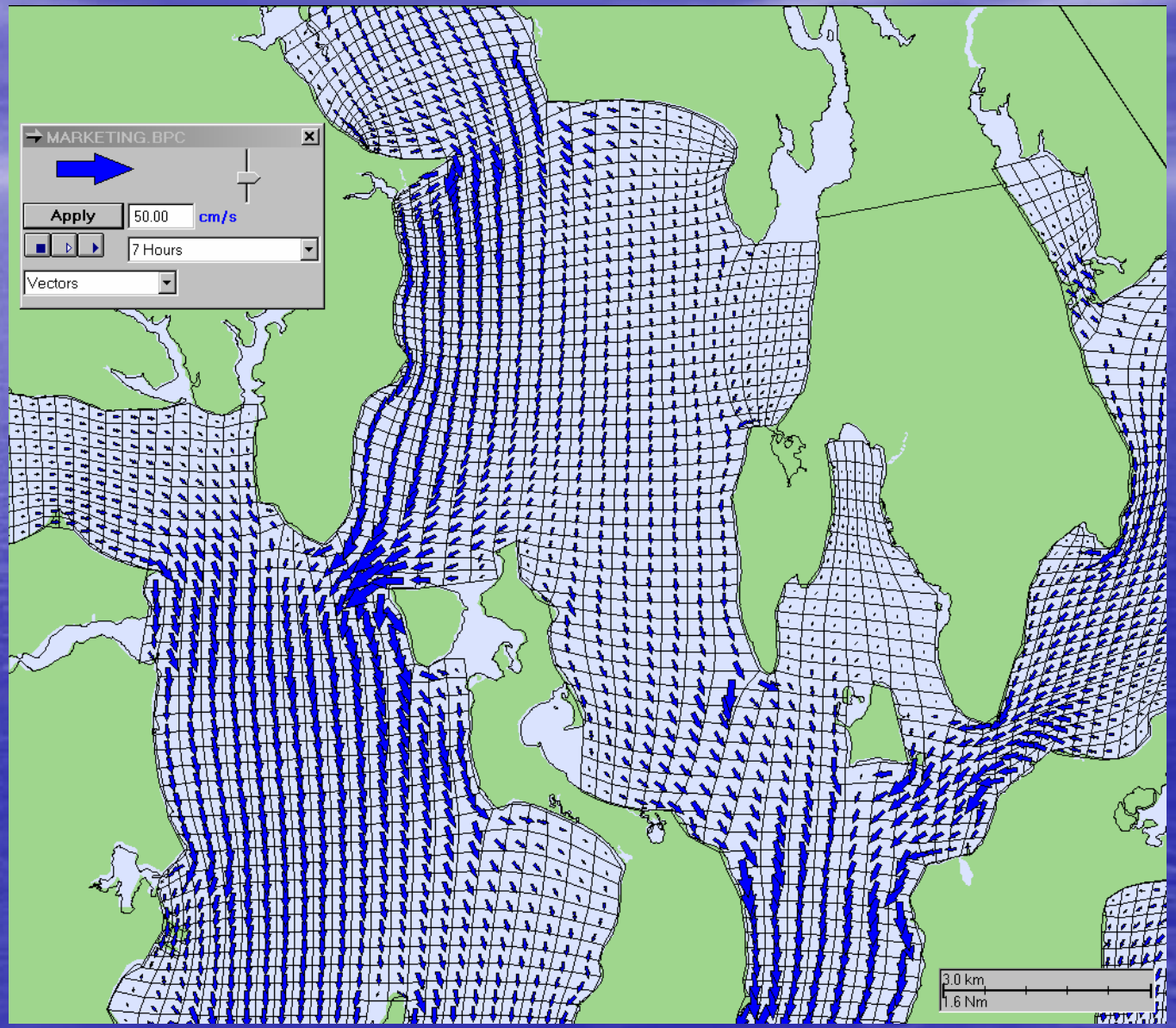
Model to Data Comparisons



- Visualize model output and data simultaneously
- Perform qualitative and quantitative time series analyses

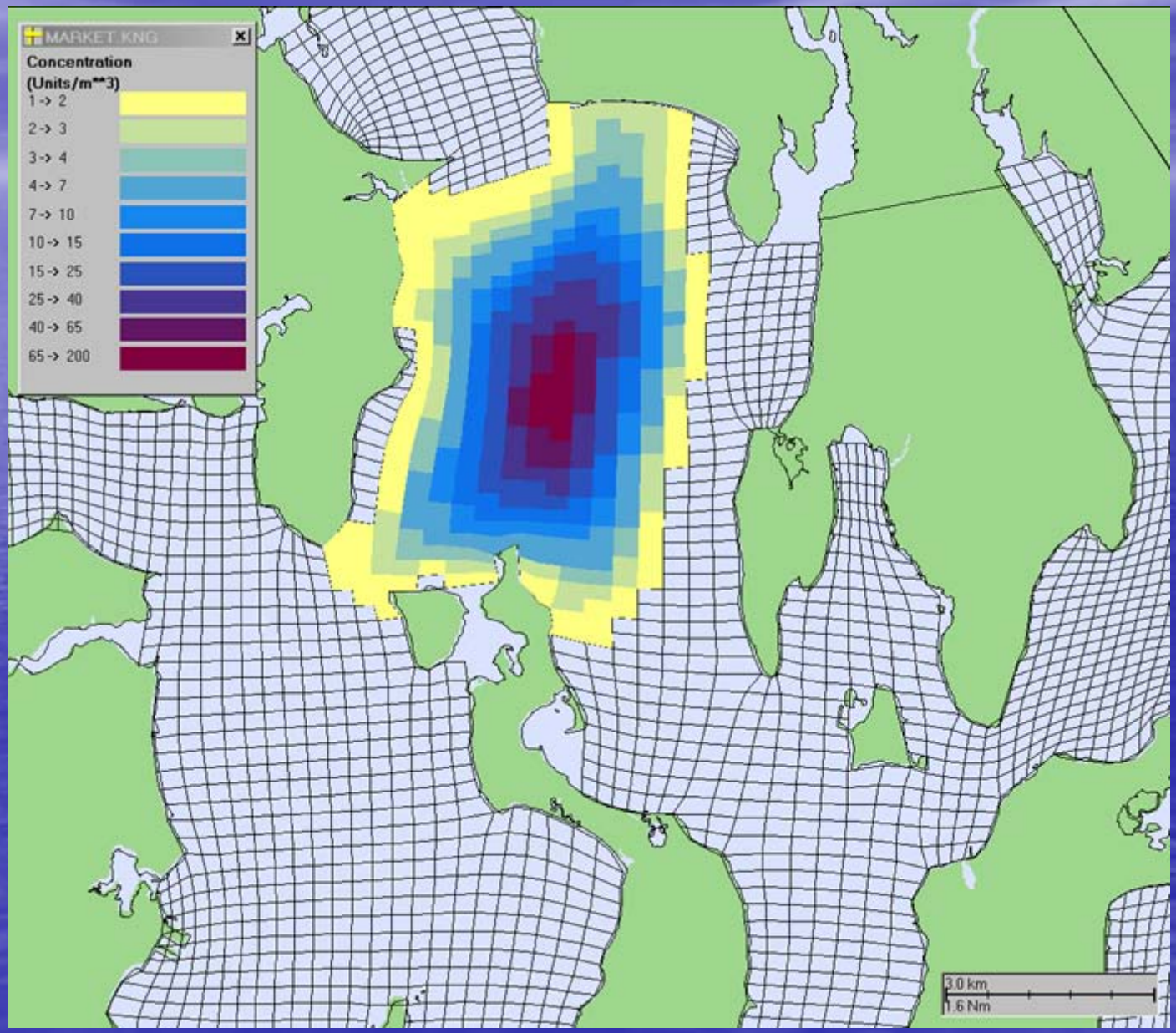
From Concept to Execution

Current Files output from Hydrodynamic Modeling Link Directly to All ASA Models



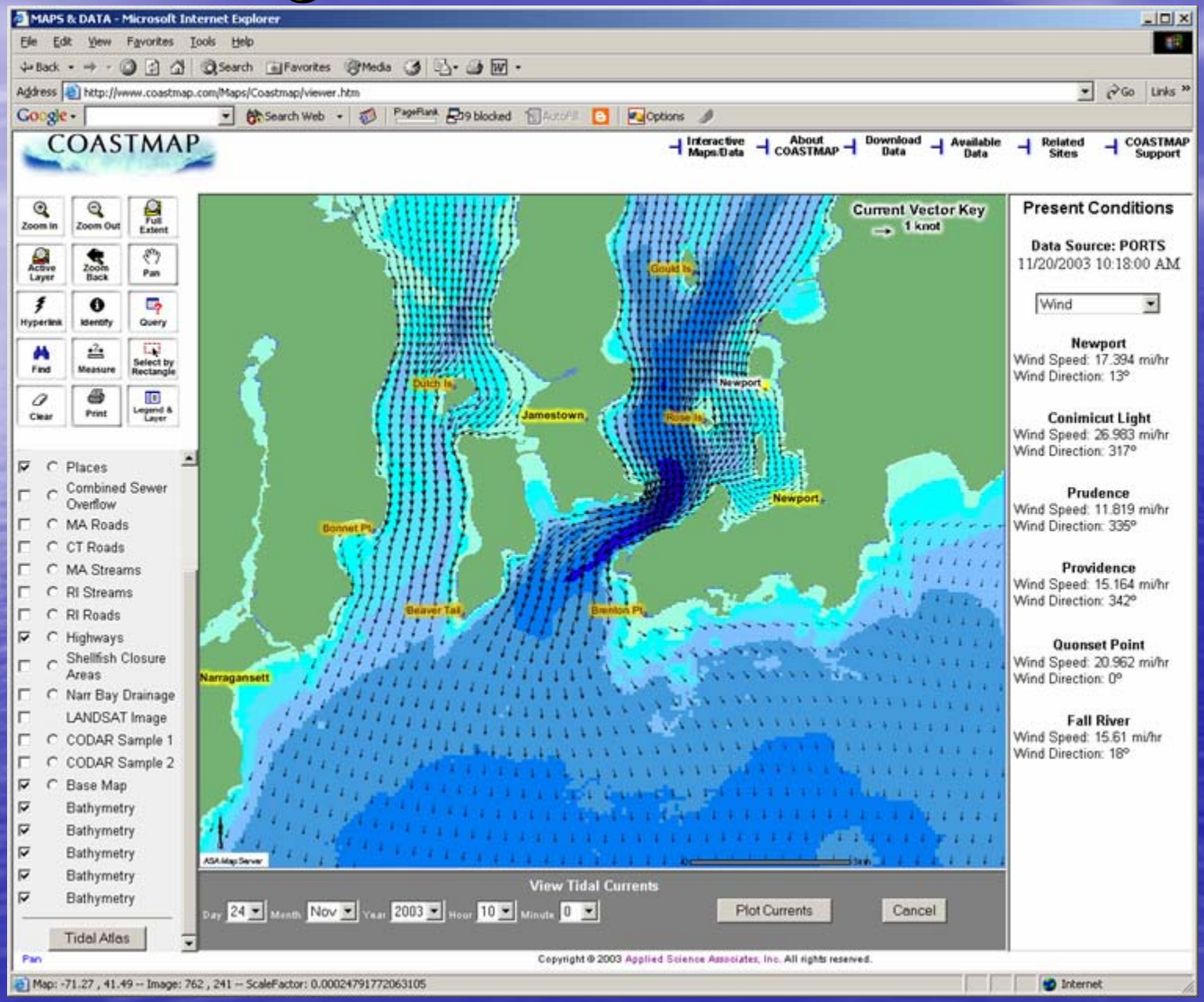
From Concept to Execution

Pollutant Transport Modeling

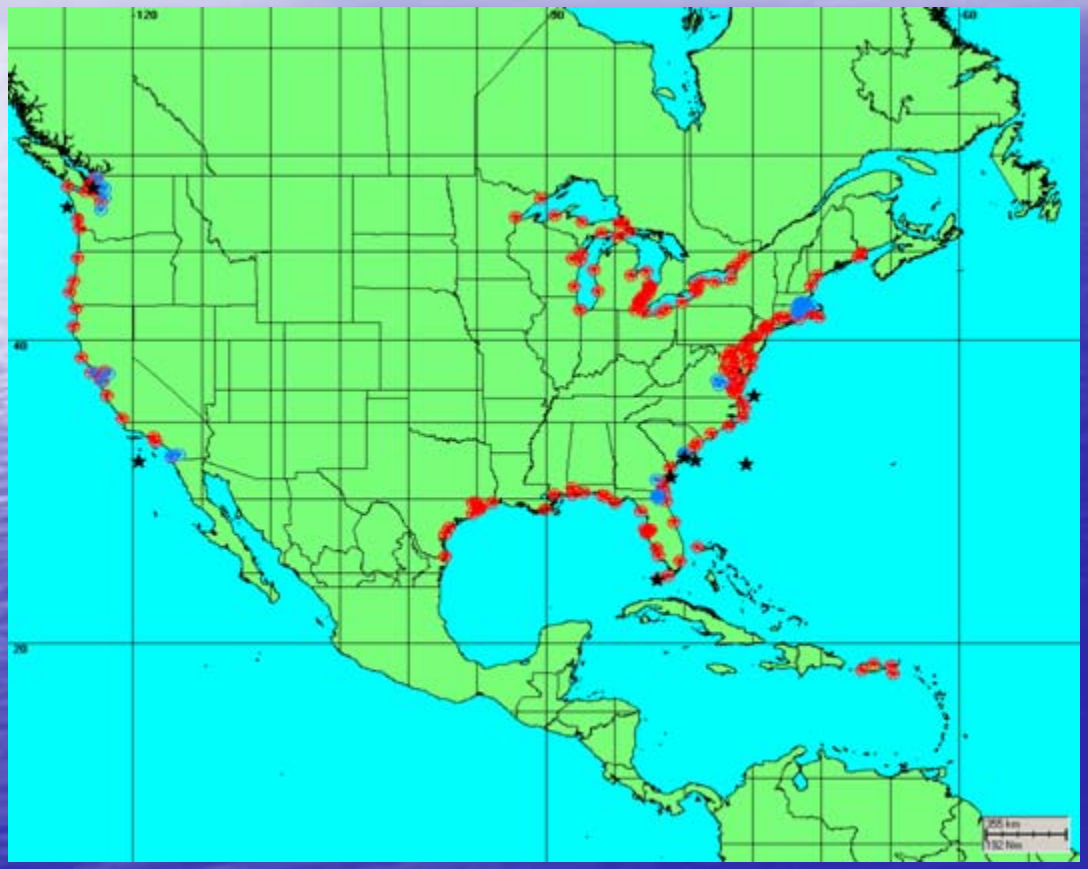


Web-Posting of Results

www.coastmap.com



US Naval Oceanographic Office



- Client/Server Application
- Real Time Data from 275 Sensors
- Support Operational Modeling and Homeland Security Activities

NAVO Coastal Ports

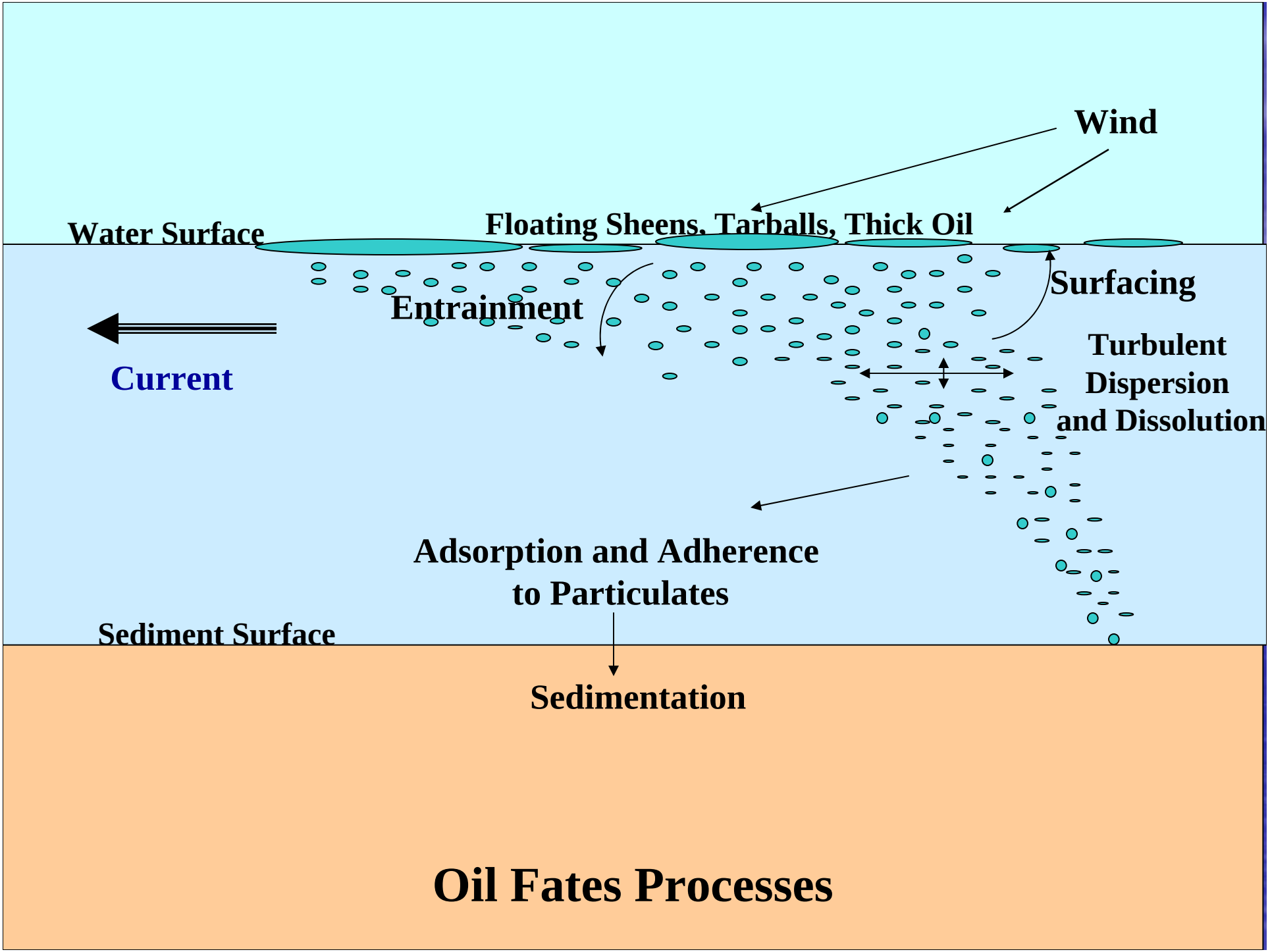
- Provide linkages to and display of real time and archived monitoring data for various ports where Navy has facilities
- Initial locations
  - Charleston, SC
  - Kings Bay, GA
  - Hampton Roads, VA
  - Puget Sound, WA
  - San Diego, CA
  - St. Johns, FL
- Data include water level, currents, river flow, waves, air and water temperature, winds, pressure

Oil Transport and Fates Models

OILMAP and SIMAP

SIMAP

- Surface slicks
- Subsurface droplets
- Water column aromatics (toxic fraction)
- Sediment aromatics
- Sediment total hydrocarbons
- Shoreline deposition and removal
- Response
- Mass balance


Wind
Water Surface
Floating Sheens, Tarballs, Thick Oil
Surfacing
Entrainment
Current
Turbulent
Dispersion
and Dissolution
Adsorption and Adherence
to Particulates
Sediment Surface
Sedimentation
Oil Fates Processes

Potential Impacts of Oil Spills

- Surface smothering/coating exposure
  - Wildlife (birds, marine mammals, sea turtles)
  - Beaches
  - Shoreline habitats (wetlands, mangroves, seagrass)
- Subsurface toxicity (aromatics)
  - Fish and shellfish
  - Food web
  - Aquatic habitats

Biological Exposure Model

- Organisms classified by behavior
  - Wildlife
    - % of time on water surface
    - Habitats used
    - Feathers & fur
  - Fish and Invertebrates
    - Swimming
    - Drift with currents
    - Stationary
- Movements of organisms are tracked to calculate exposure of individuals
- Impact a function of dose
  - Wildlife
    - Area swept by oil
    - Oil thickness
  - Fish and Invertebrates
    - Concentration
    - Exposure time
    - Temperature

Validation

- Model validated for >30 cases
  - *Exxon Valdez*
  - *North Cape*
  - *Puerto Rican*
  - *Command*
  - *Apex Houston*
- Model accuracy depends on:
  - Environmental data
    - Winds
    - Currents
  - Biological data
    - Toxicity (species sensitivity)
    - habitat mapping
    - abundances

Example:
Hindcast / Nowcast / Forecast

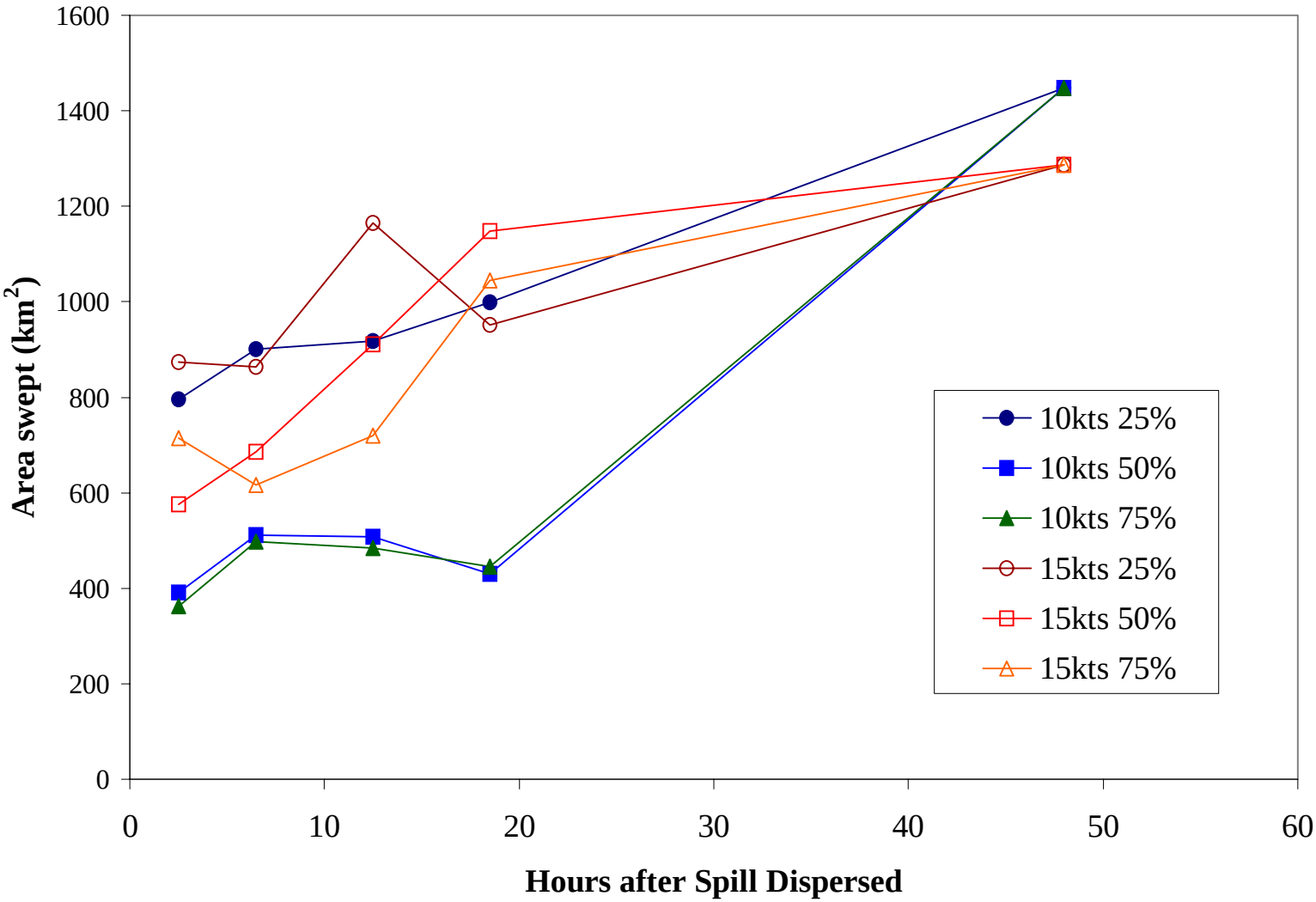
(demo)

Example: 1 million gal AK NS crude

Impact	No Dispersant	With Dispersant
Surface oil	50% of total	All dispersed
Dissolved aromatics	Up to 100 ppb	Over 1 ppm
Wildlife	3590 km^2	81 km^2
Water at surface	0.2 km^2 (200 kg sm. fish)	12 km^2 (43,000 kg sm. fish)

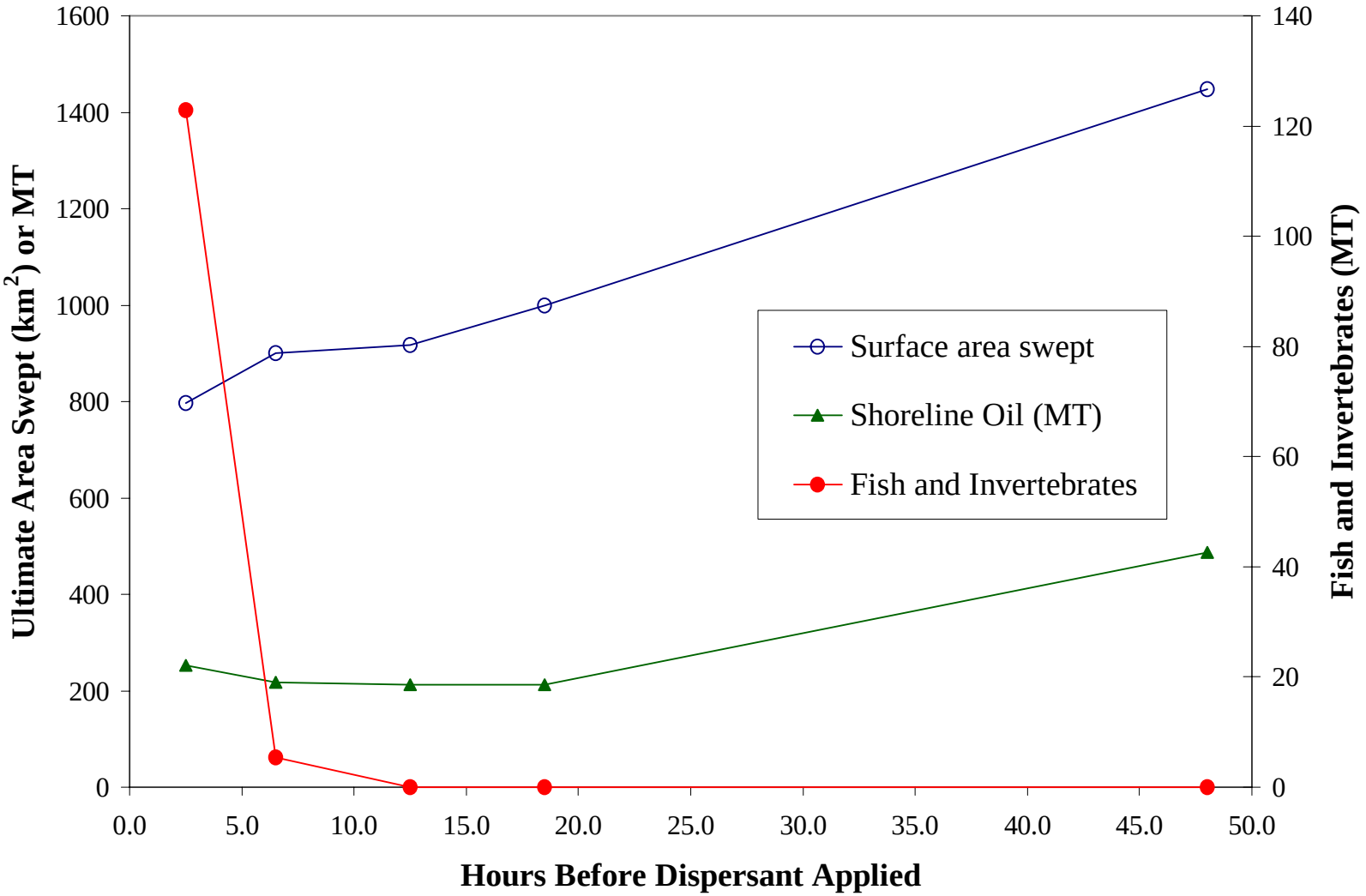
400,000 gal LA Crude

Surface Swept by Oil



400,000 gal LA Crude

Wind 10 kts, 25% Dispersed



Model Approaches for Ecological Risk Assessment and Spill Response Planning

- Single Scenarios
  - Hindcast
  - Representative
  - Worst case
- Multiple scenarios in Stochastic Mode -- for potential spill site(s) and release scenarios
  - Probability of exceeding thresholds of concern
  - Probability of impacts

Single Scenario Assessments

- Run a representative or worst case spill
- Sensitivity analysis: Vary data inputs to describe uncertainty
- What if assessment: Vary response to evaluate change in impact

Multiple Scenarios

- Uses
  - –Response planning
  - –Response equipment deployment
  - –Ecological risk assessment
  - –Cost / benefit
  - –Identification of worst case scenario
- Quantifies probability and expected degree of oil contamination and impact

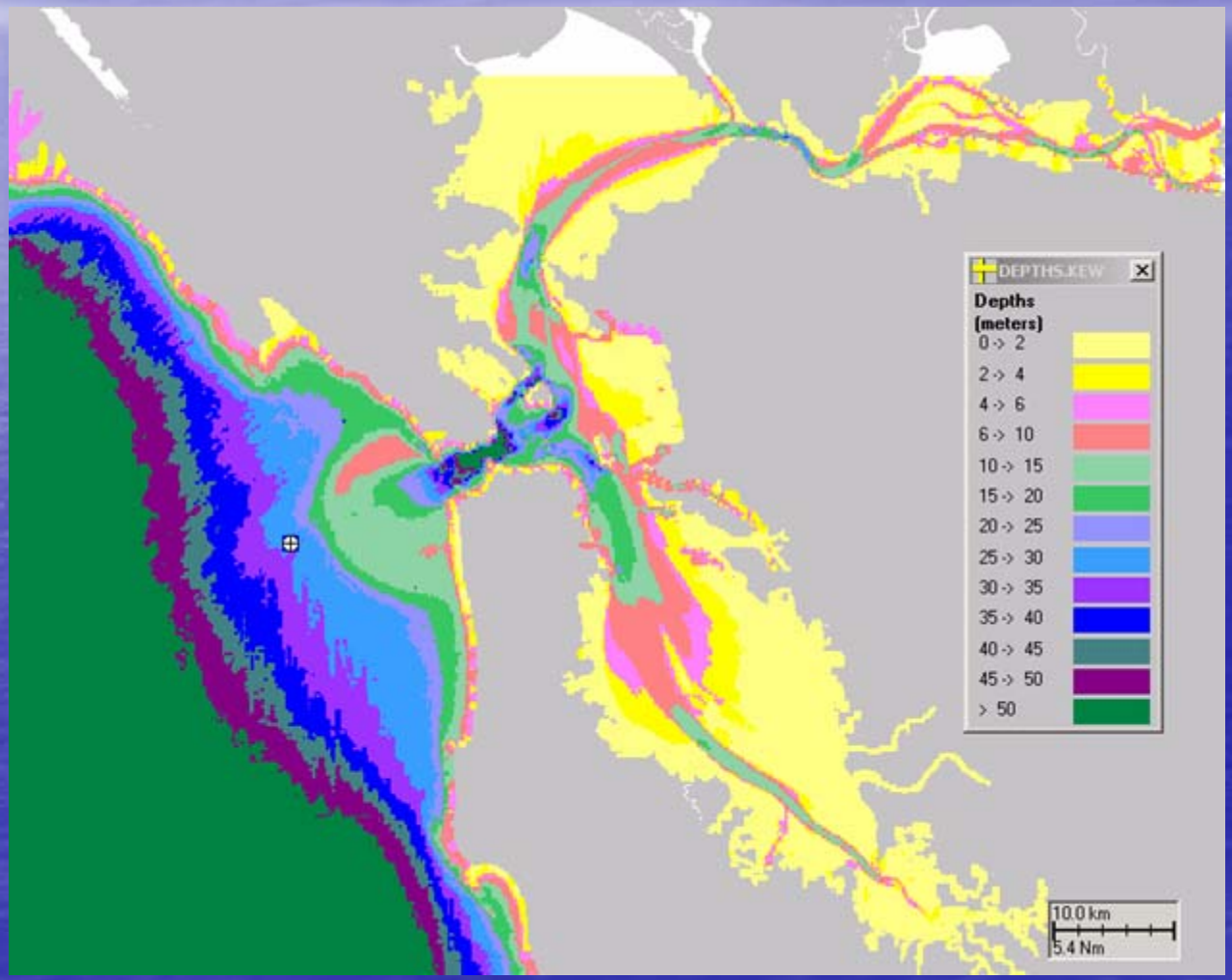
Stochastic Model

- Input data
  - Long term wind record
  - Currents
    - Long term current record
    - Hydrodynamic model
- Run model many times, randomize:
  - Spill date and time, and so winds and currents
  - Volume, duration, other inputs (Monte Carlo)
- Output: Statistical distributions of results

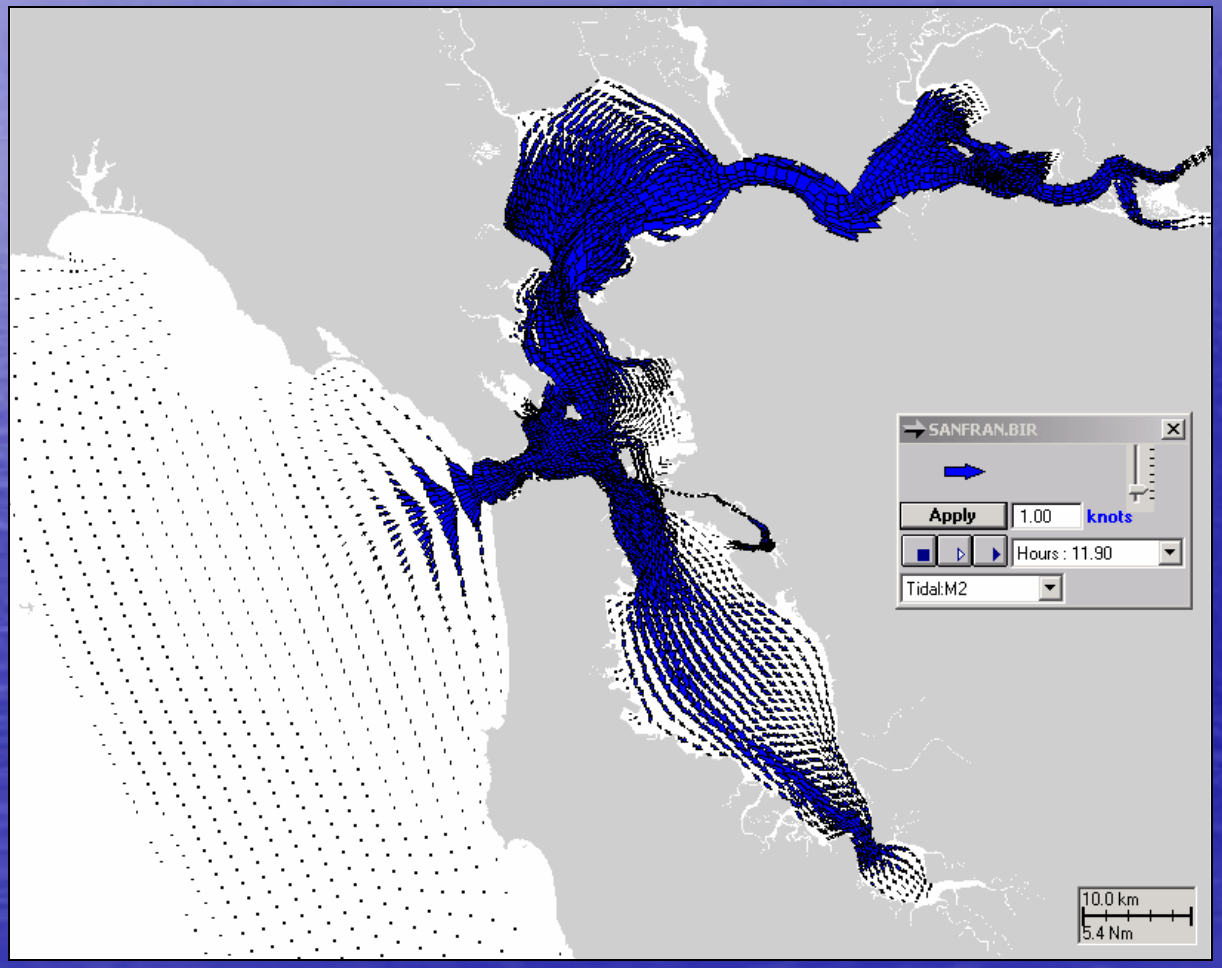
Example:
40,000 bbl (1.68 million gal) spills off San Francisco Bay

- Modeling study for US Coast Guard
- Programmatic Environmental Impact Statement (PEIS)
- Proposed changes to Vessel and Facility Response Plan oil removal capacity (Caps) requirements for tank vessels and marine transportation-related facilities

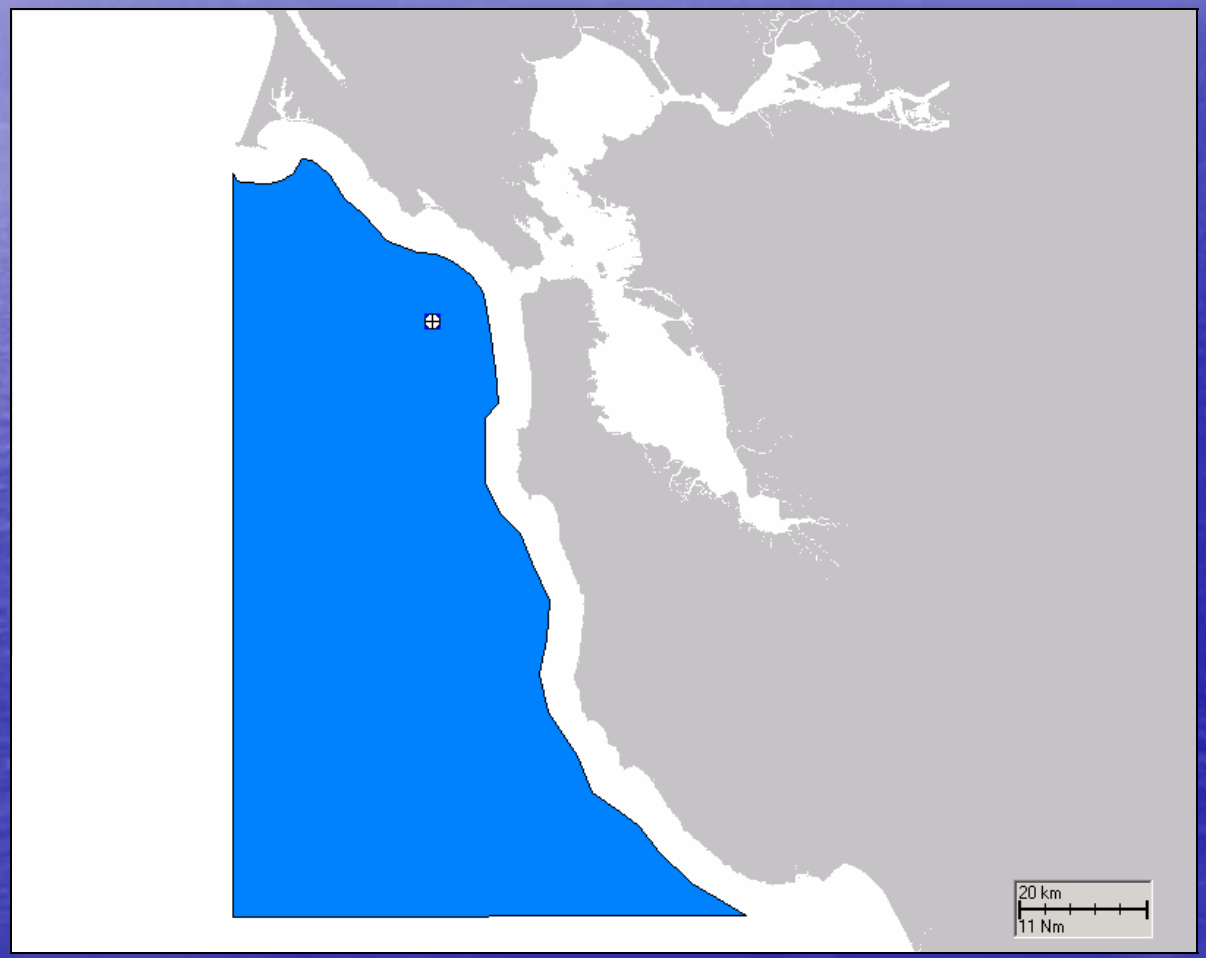
What if a Spill
7 miles from Golden Gate?



Hydrodynamic Modeling

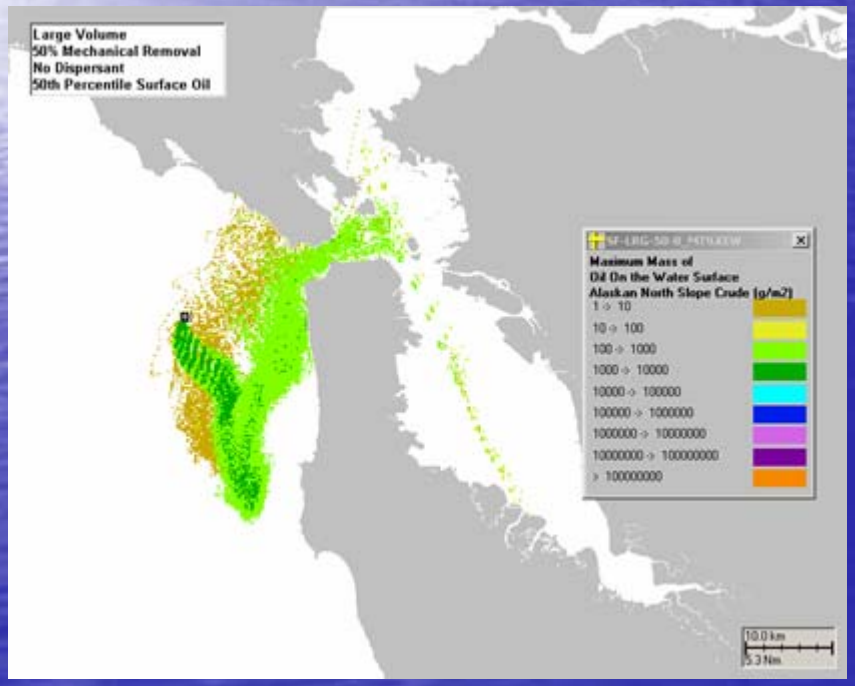


Dispersant Application Area

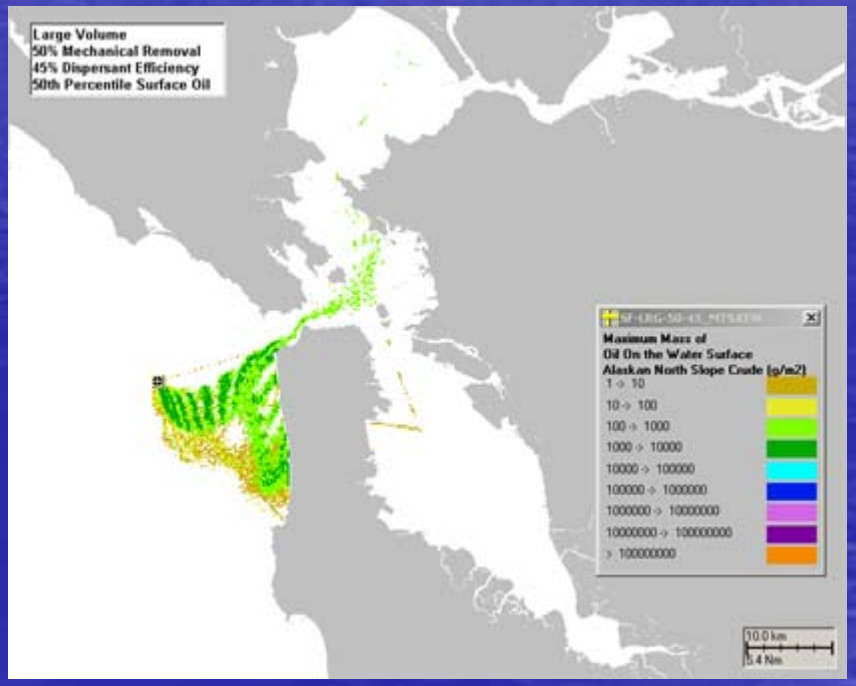


Oil on Water Surface – Amount for one spill date and time

No Dispersant

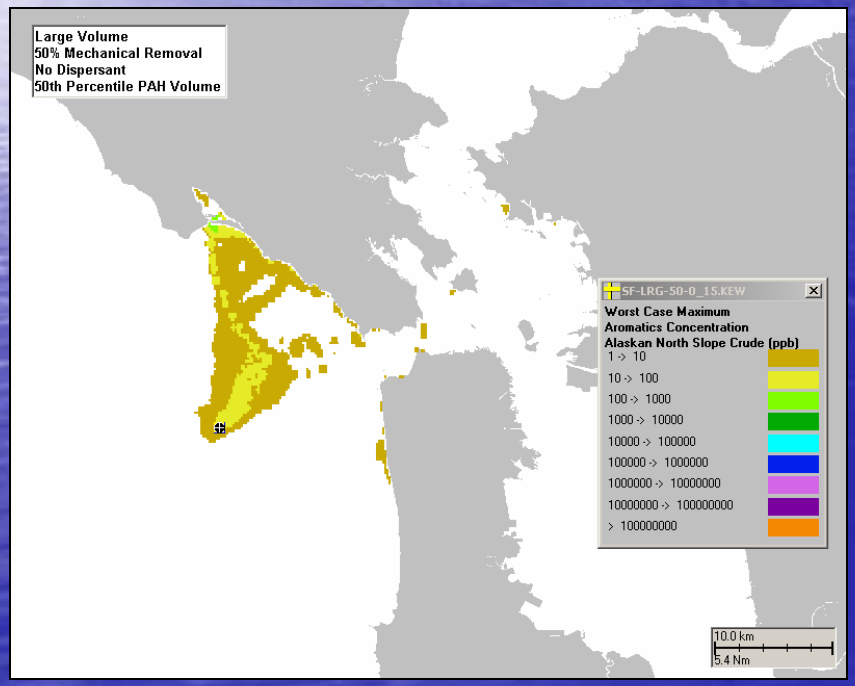


With Dispersant

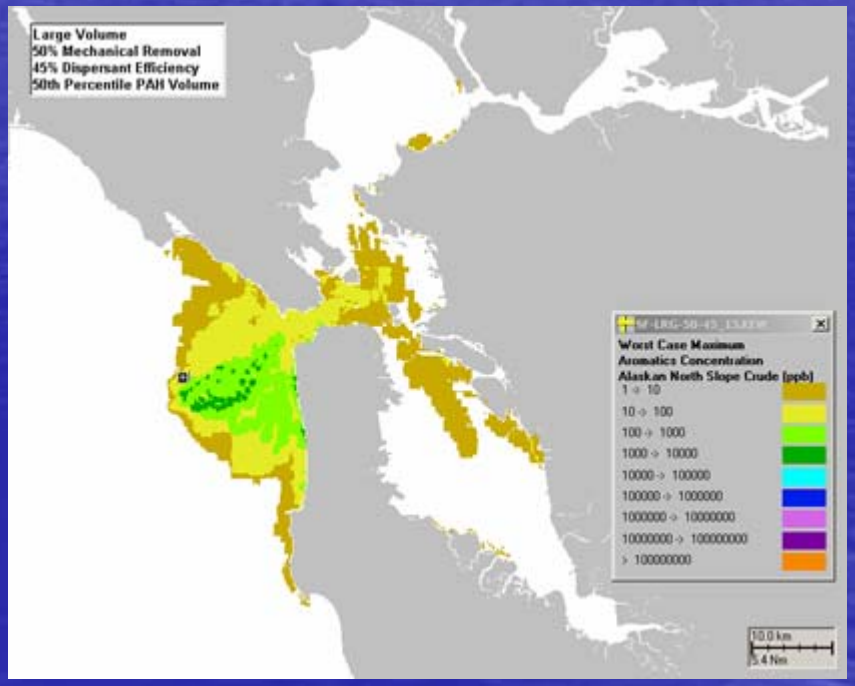


Dissolved Aromatics – Maximum Concentration for one spill date and time

No Dispersant

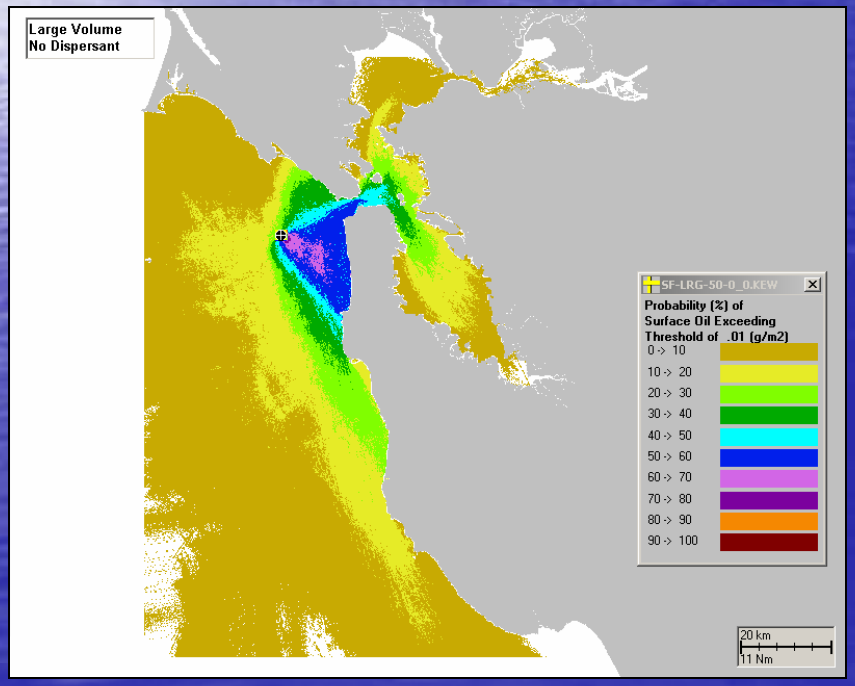


With Dispersant



Oil on Water Surface – Probability

No Dispersant



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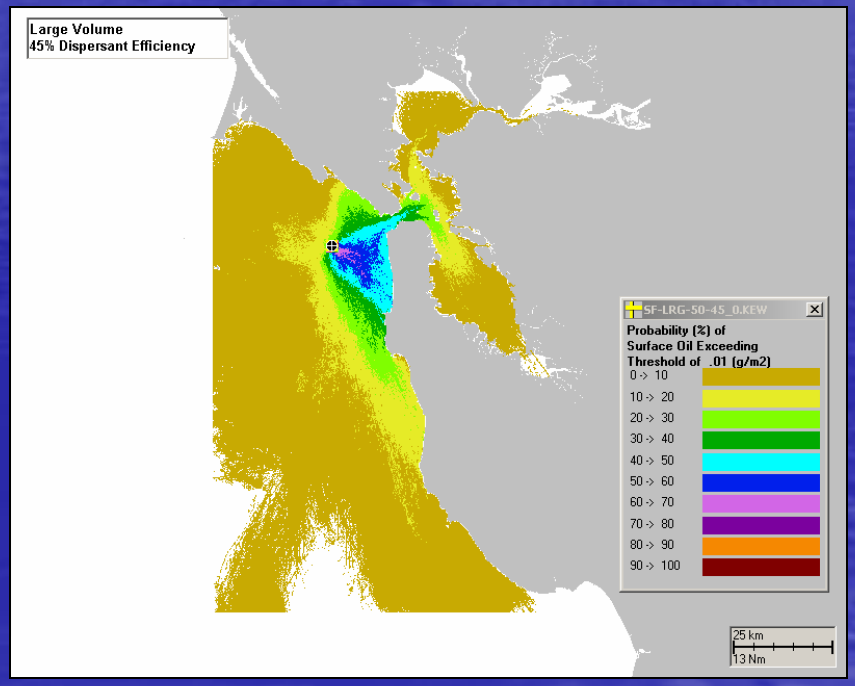
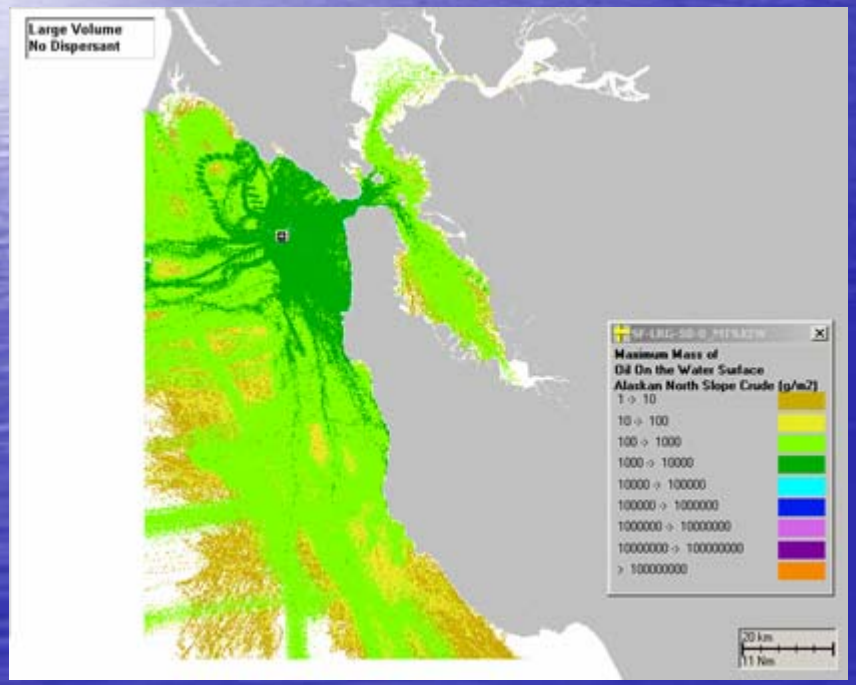


Oil on Water Surface – Amount

No Dispersant



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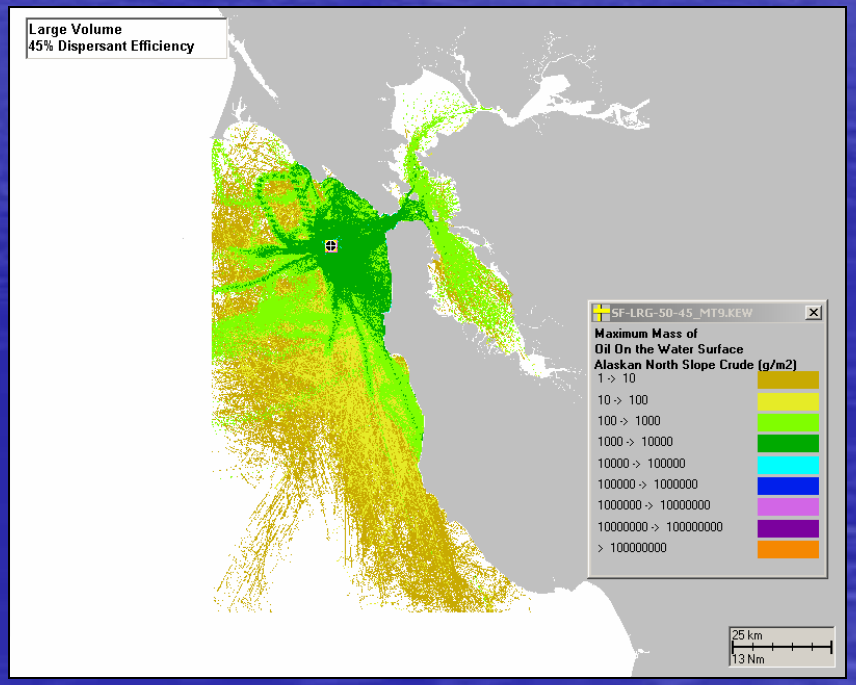
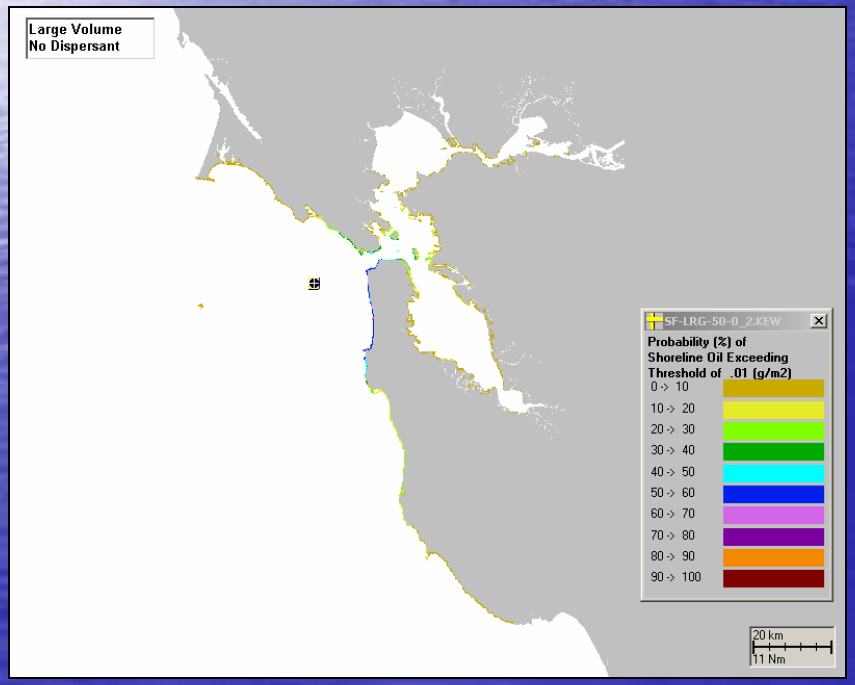
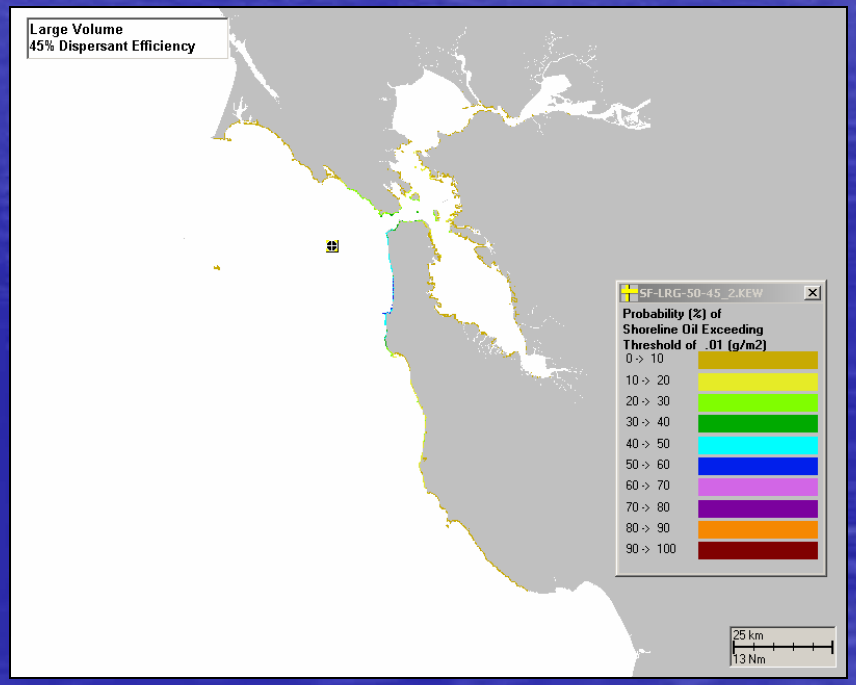


Shoreline Oiling – Probability

No Dispersant

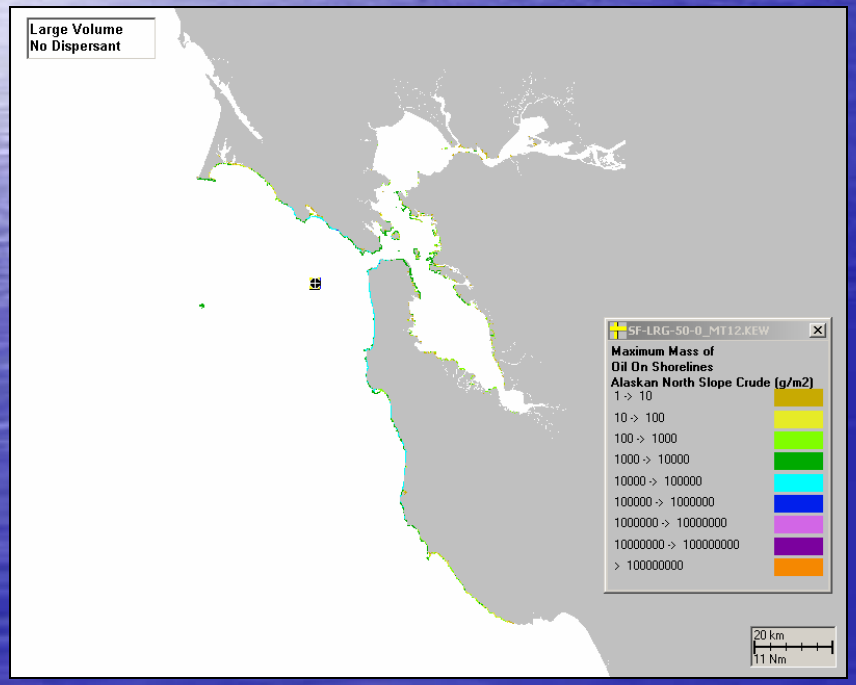


With Dispersant

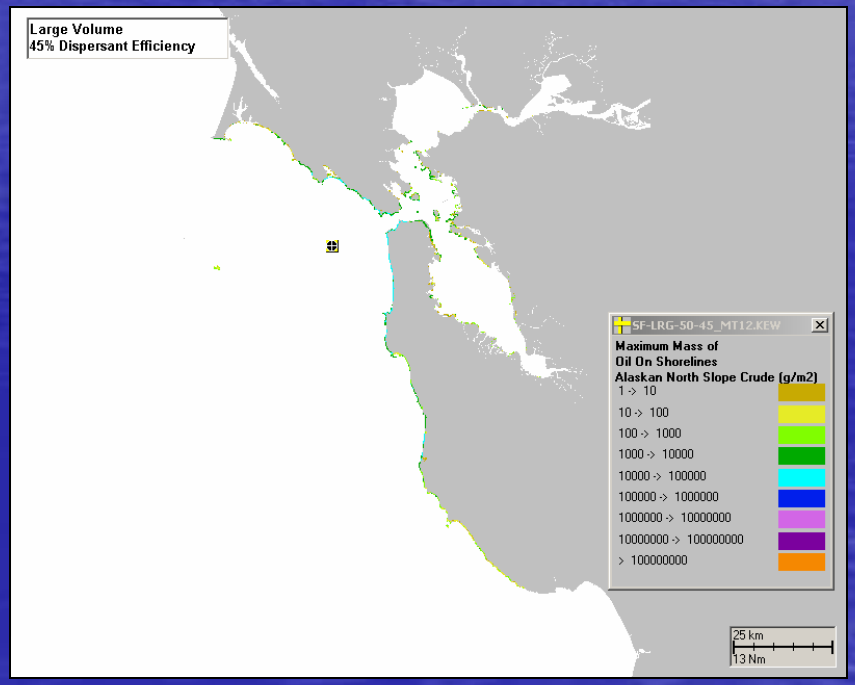


Shoreline Oiling – Amount

No Dispersant

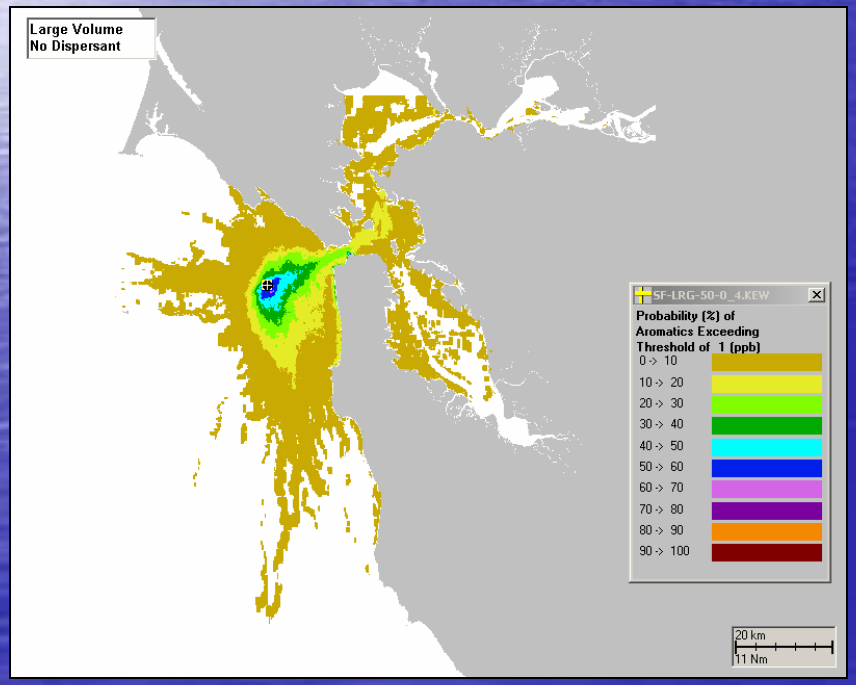


With Dispersant



Dissolved Aromatics – Probability of Exceeding 10 ppb

No Dispersant



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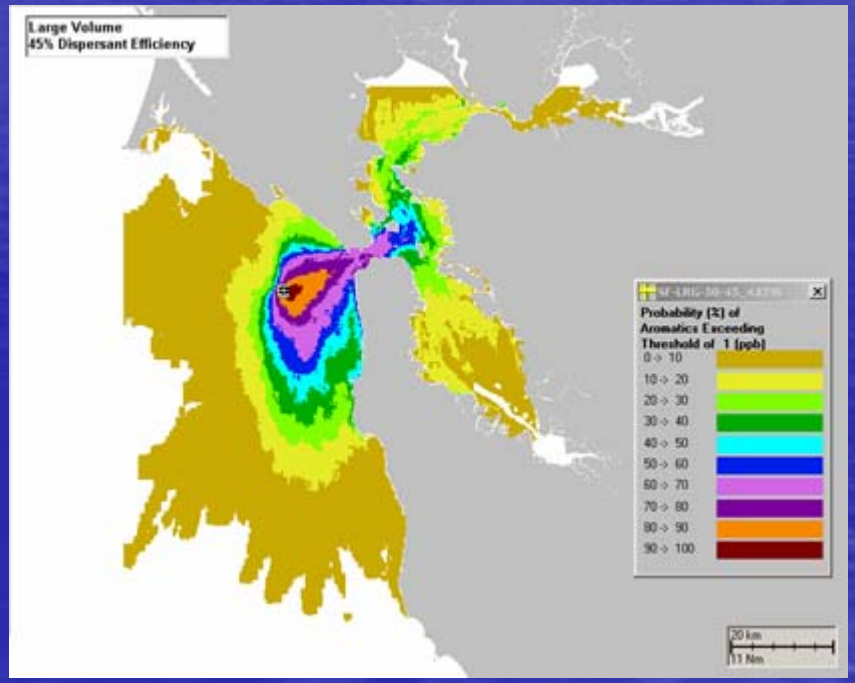
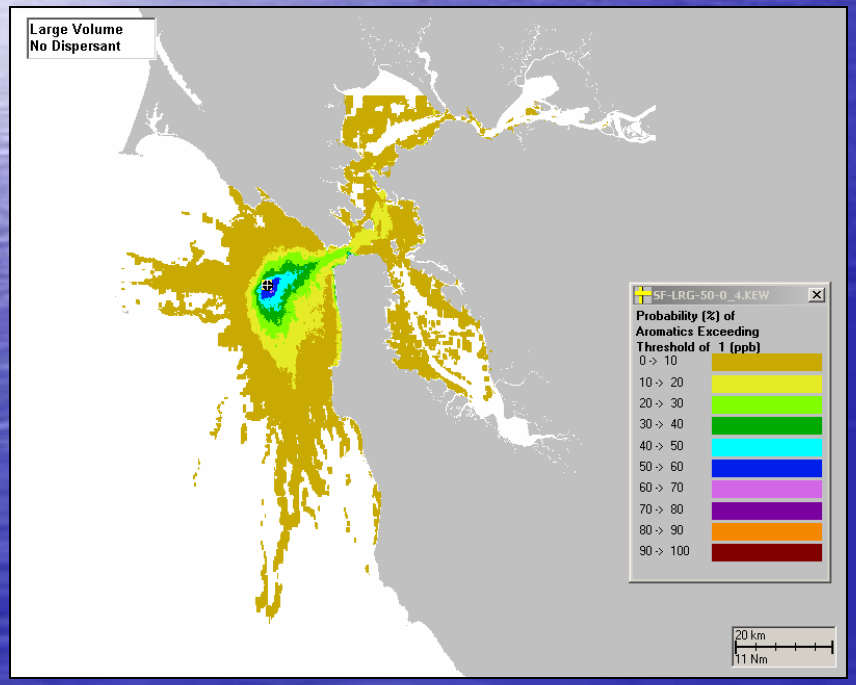


Dissolved Aromatics – Amount

No Dispersant



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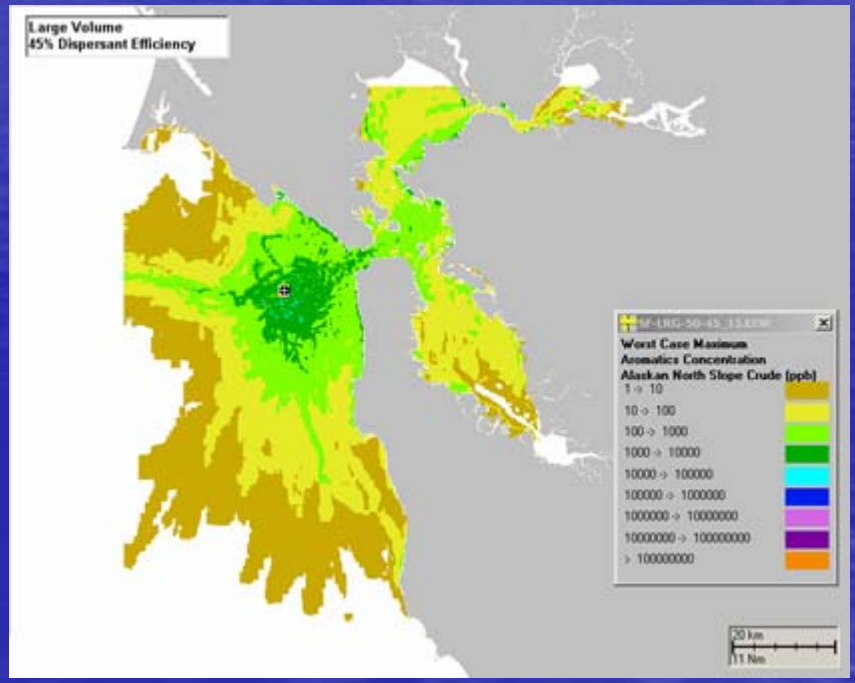
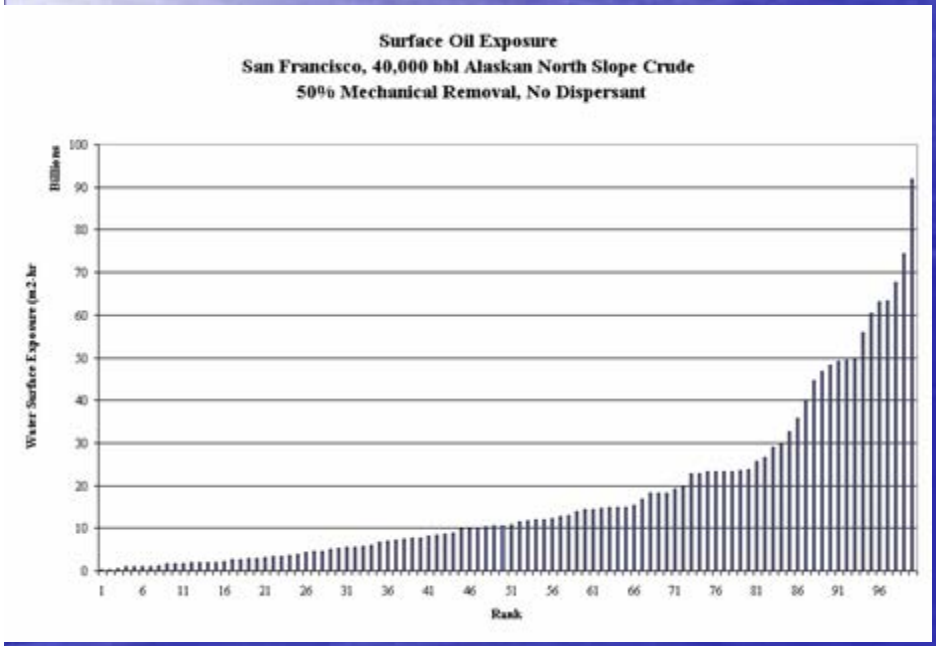


Oil on Water Surface

No Dispersant



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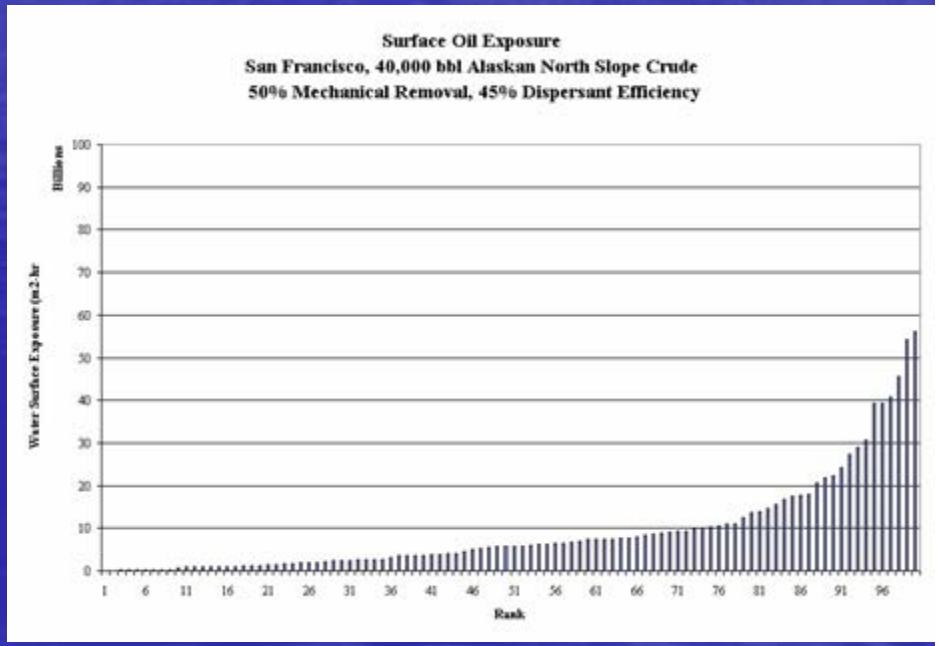
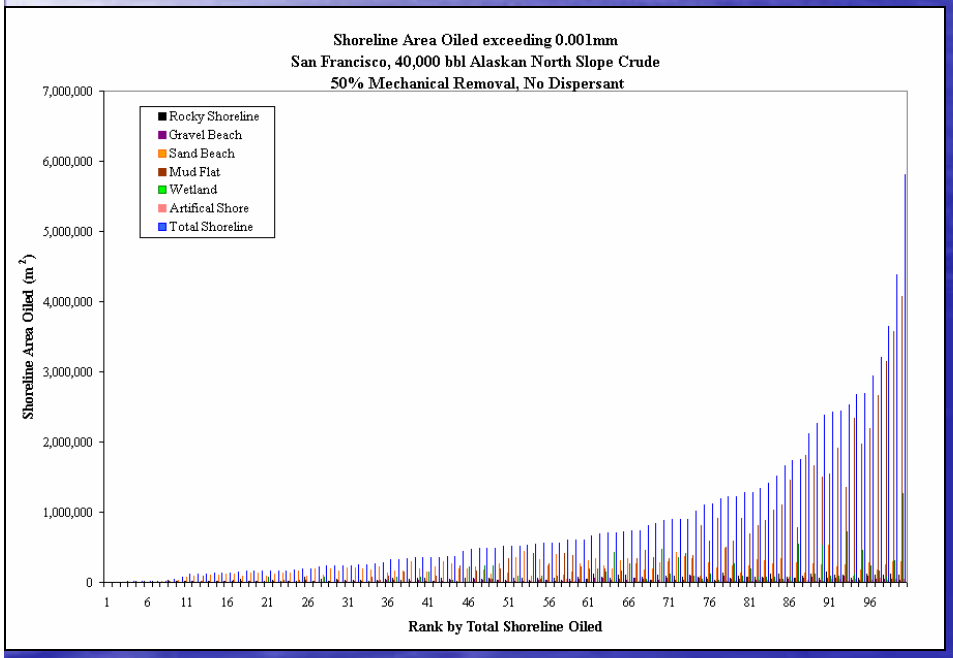


Shoreline Oiling

No Dispersant



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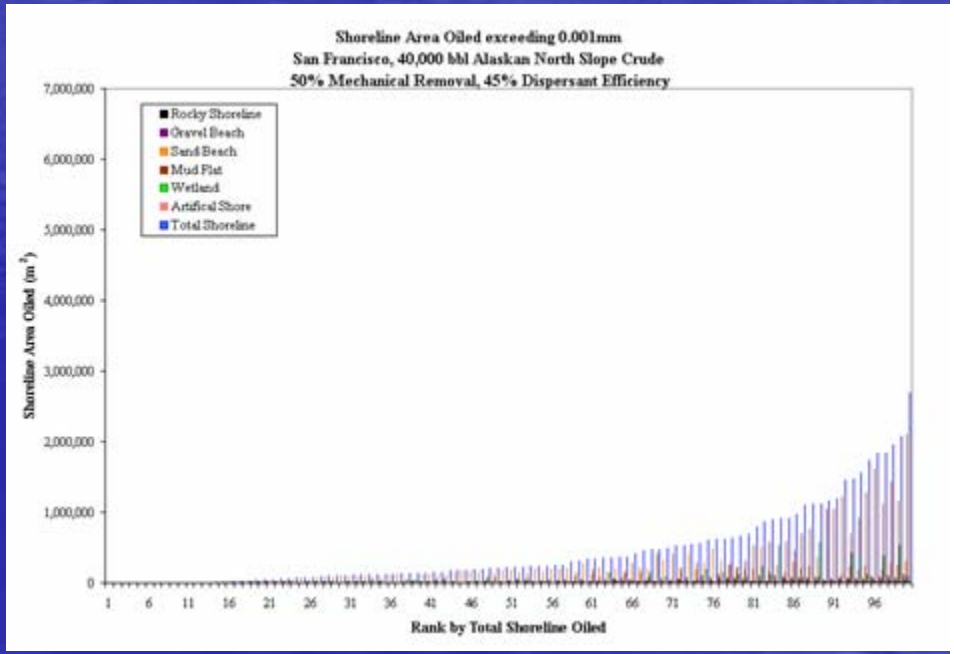
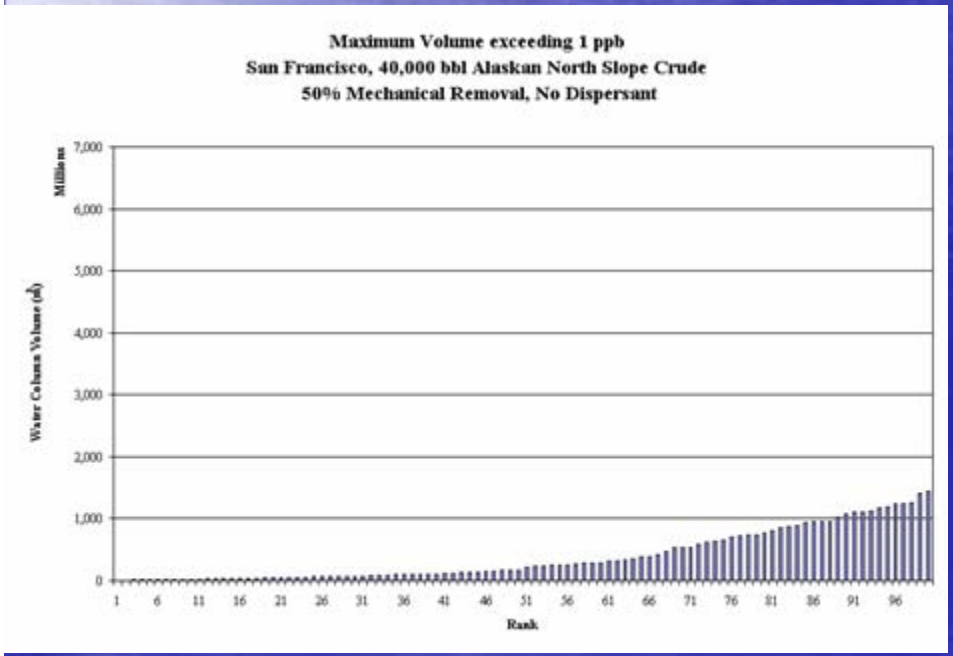


Dissolved Aromatics

No Dispersant



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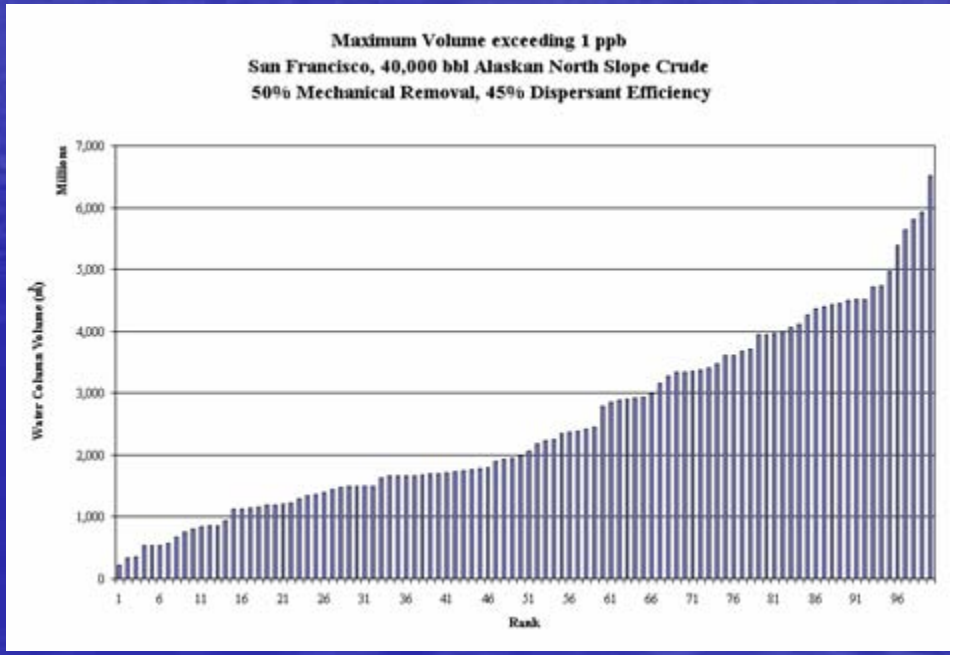

Conclusions

- Large and Powerful Toolbox
  - Models: Oil, Chemicals, Hydrodynamics
  - Acquisition, analysis and incorporation of real-time data
- Model Accuracy Depends on Data Input
- Need to Use Stochastic / Statistical Approach
- Pre-spill Preparation: makes real-time modeling and analysis possible